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Papers 1-9 are contributions No. 236 and 238-245 from the Botanical Laboratories of Butler University. Paper No. 10 is based upon work done at the University of Illinois by a graduate of Butler University.

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# THE DISTRIBUTION OF THE FERNS AND FERN ALLIES FOUND IN INDIANA<sup>1</sup>

By SARAH CLEVENGER

The list of Pteridophyta found in Indiana was compiled from the "Flora of Indiana," by Charles C. Deam (3) and the yearly supplementary distribution records prepared by the State Flora Committee of the Indiana Academy of Science (4-11). The publications give the state distribution by counties. For data concerning the national distribution and various state floras, manuals of wider scope and periodical literature were used. The national distribution of the Indiana ferns and fern allies was mapped as accurately as possible, and from these maps the determination of intraneous and extraneous species was made.

Deam (3) recognizes six floral areas in Indiana (figure 1). They are: the Lakes area, the Tipton Till plain, the Illinoian Drift area, the Prairie area, the Lower Wabash Valley area, and the Unglaciaded area. The limits of these areas are determined by physiographic features which have been described by him and each has a characteristic flora.

## INDIANA DISTRIBUTION

The range of a species in the state was plotted by counties from data given by Deam in his Flora of Indiana (3) and from additional plant distribution records (4-11) prepared by the State Flora Committee of the Indiana Academy of Science and published annually. From these additional records, four taxonomic entities have been added to the list of Indiana Pteridophyta as it originally appeared in the "Flora of Indiana."

Benton County is the only county which is entirely included in the prairie area and it was used as an index in determining whether or not a species was found in the prairie area. The ferns and fern allies listed by Peattie (18), Lyon (15), and Tryon (20) were recorded

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<sup>1</sup> A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

as being found in the Dunes area. For the Lower Wabash Valley area, the pteridophyta listed by Schneck (19) were considered to be the only species found in this area. The other areas were more easily delimited.

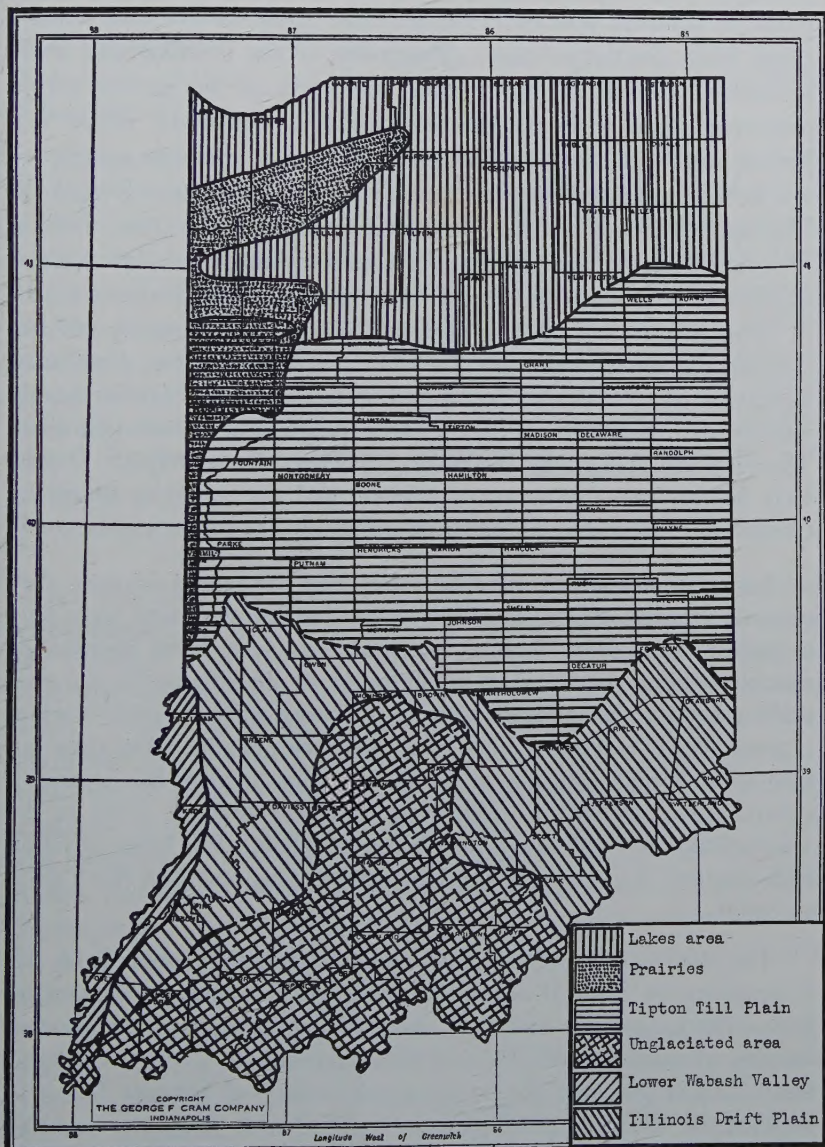
TABLE I  
Tabulation of Pteridophyta Found in Indiana

|                 | Genera | Species | Varieties | Forms | Hybrids | Totals |
|-----------------|--------|---------|-----------|-------|---------|--------|
| Ophioglossaceae | 2      | 6       | 3         | 1     | 0       | 10     |
| Osmundaceae     | 1      | 2       | 1         | 3     | 0       | 6      |
| Polypodiaceae   | 16     | 30      | 9         | 5     | 5       | 49     |
| Salviniaceae    | 1      | 1       | 0         | 0     | 0       | 1      |
| Equisetaceae    | 1      | 8       | 0         | 0     | 0       | 8      |
| Lycopodiaceae   | 1      | 5       | 1         | 0     | 0       | 6      |
| Selaginellaceae | 1      | 2       | 0         | 0     | 0       | 2      |
| Isoetaceae      | 1      | 1       | 0         | 0     | 0       | 1      |
| Totals          | 24     | 54      | 15        | 10    | 5       | 84     |

The Indiana Pteridophyta represents 8 families, 24 genera, 54 species, 15 varieties, 10 forms, and 5 hybrids (table I). Of these 84 taxonomic entities, 41 are recorded in less than 10 counties and 24 have been found in only one or two counties. Only 14 are found in over 40 counties; no one species is on record from every county, though it is almost certain that a number of species actually do occur in every county in the state.

Cowles (1) states that the flora of the region is composed of two elements. One element consists of those species that are found in the region and in all directions from that region and are termed *intraneous* species. The other element is made up of three groups, (1) *extraneous* species which are found in the region, but are not found in all directions from the region, (2) *disjunct* species which are found in isolated colonies outside their continuous range, and (3) *endemic* species which are found only in that region. No pteridophyte species belonging to the latter two groups are known in Indiana.

Forty-nine species were found to be intraneous in Indiana. Of these intraneous species, *Adiantum pedatum*, *Equisetum arvense*, *E. prealtum*, *Dryopteris noveboracensis*, *Botrychium dissectum* var. *obliquum*, *B. virginianum*, and *Polystichum acrostichoides* are typical, being found throughout the state.



Indiana, by virtue of its geographical location, is often on the northern range limits of southern species and on the southern range limits of northern species (Friesner, 13). The eastern and western range limits are not so clear. Thirty-one of the Pteridophyta found in Indiana are extraneous species. Elements of the eastern or appalachian flora, such as *Pellaea glabella*, *Lycopodium selago* var. *patens*, and *Isoetes engelmannii*, enter Indiana in much the same manner as the southern elements and are found in the eastern lobe of the Illinoian drift area and in the Unglaciaded area. A few, such as *Woodwardia virginica*, *Lycopodium tristachyum*, and *Lycopodium obscurum*, are eastern and northeastern species. The almost total lack of ferns in the Great Plains region eliminates the necessity of considering the western element, for only two Pteridophyta, *Equisetum kansanum* and *E. laevigatum*, found in Indiana, have predominantly western distributions, and their eastern range limit is found in Ohio. The northern group may be typified by *Botrychium simplex*, *Dryopteris bootii*, and *Equisetum fluviatile*; and the southern group by *Cheilanthes lanosa* and *Polypodium polypodioides* var. *michauxianum*.

Some species which must be classed as intraneous because they occur in similar habitats in all directions outside the state, have only a limited distribution within the state. In such cases absence of suitable habitats, rather than wider range of distribution is the controlling factor. Examples are found in *Dennstaedtia punctilobula* and *Asplenium trichomanes*. Each of these species has its wider distribution surrounding Indiana on all sides. The former has a known occurrence in Indiana in only four counties, three of them in the Unglaciaded area and one in the Tipton till plain. The latter is found in 8 counties, 5 of them in the Unglaciaded area and 3 in the Tipton till plain.

The distribution according to floral areas is given in Table II. A summary of Table II is found in table III. As may be seen in the tables, the Lakes area and the Unglaciaded area contain the greatest number of entities with 74% and 67% respectively, of the total number. This is probably due to the great variety of habitats found in both areas. The Tipton till plain ranks third with 55 species or 65%. It might be expected that this region, which is the largest of the floral areas, would have the greatest number of species, but due to extensive cultivation of the land, the disappearance of the forests, the draining

of the swamps, and the grazing of hillsides, many fern habitats have been destroyed. The Illinoian drift area is next with 56%, while the Prairie area and the Lower Wabash Valley area have only 8% and 28%, respectively. Only 4 species are found in all of the floral areas. They are: *Onoclea sensibilis*, *Pteridium aquilinum* v. *latiusculum*, *Equisetum arvense*, and *E. prealtum*.

Not enough data were available to determine the national range of 9 of the 84 entities of Pteridophyta found in Indiana. Three-fifths of the plants whose ranges were determined are found in central United States and are intraneous to Indiana. The remaining two-fifths reach their range limits within Indiana. Of the extraneous entities, 15 or 55% are found in the Unglaciaded area and a similar number in the Lakes area. The Illinoian till plain is next in order with 10 and the Tipton till plain follows with 9 entities. The Tipton till plain contains the largest number of intraneous species, followed closely by the Lakes area, the Illinoian drift plain, and the Unglaciaded area.

#### UNITED STATES DISTRIBUTION

Of the 75 species, varieties, and forms whose national distributions were mapped, 55 were limited to the central and eastern portion of the country. Only 13 were found west of the Rocky Mountains. Many of the eastern ferns find their range limit in the central lowlands. Over 80% of the entities are found in the Appalachian Highlands and the Interior Low Plateaus. The Interior Highlands contain 76% of the entities while the Central Plains and the Laurentian Uplands have 57% and 59% respectively. The Great Plains (with the exception of the Black Hills of South Dakota), the Wyoming Basin, and the Southern Rocky Mountains each has less than 10% of the Indiana species within their boundaries. The percentages rise to 13 for the Intermontane Plateaus and to 15.5 for the Pacific Coast states.

The following Indiana species are found in the Pacific Coast states: *Ophioglossum vulgatum*, *Botrychium virginianum*, *Cystopteris fragilis*, *Asplenium trichomanes*, *Equisetum arvense*, *E. fluviatile*, *E. kansanum*, *E. variegatum*, *E. laevigatum*, *E. prealtum*, *Lycopodium inundatum*, *L. obscurum*, and *L. selago* var. *patens*. In addition, a few eastern species are represented in the Pacific Coast states by closely related varieties. For instance, *Adiantum pedatum* var.

*aleuticum* and *Pteridium aquilinum* var. *lanuginosum* are found in northern North America and along the Pacific coast, while their eastern counterparts, *Adiantum pedatum* and *Pteridium aquilinum* var. *latiusculum* have a more southern range. Hanna (14) states that intergrades between *Pteridium aquilinum* var. *latiusculum* and *P. aquilinum* var. *lanuginosum* are found in Wyoming.

Many of the eastern species find their western limits in the states bordering on the Mississippi River and then are present in the Black Hills of South Dakota. This area has a unique flora, for plants are found here which are not found in the neighboring regions (McIntosh, 16).

Table II lists the 27 extraneous species and gives the compass directions of their distribution outside Indiana. Twenty-five or 92% of these extraneous species are found northeast of Indiana or in the northern portion of the Appalachian Highlands. Almost 70% are found east and 61% southeast of Indiana. These three directions include the Appalachian Highlands which contain 84% of the Indiana Pteridophyta. The southwest, south, and north directions have percentages of 58, 55, and 52, respectively. The weakest affinity is to the west and northwest. It would be expected that the affinity to the west would be weaker than it turns out to be; the higher affinity is due to the fact that a few of the eastern species find their western limits in Illinois and, though they are found west of Indiana, they are not truly western plants. Thus it is seen from the national distribution of the 75 entities of Indiana Pteridophyta as well as from the distribution of the extraneous group that the strongest affinity in distribution is to the Appalachian Highlands or in the directions of northeast, east and southeast.

## SUMMARY AND CONCLUSIONS

1. There are 84 species, varieties, and forms of Pteridophyta found growing outside of cultivation in Indiana. Of these, 24 may be considered rare since they are found in only one or two counties.

2. Four species or 5% of the total number are found in all of the floral areas. The Lakes area contains the greatest number of species, having 74% of the total, with other areas containing the following percentages: Unglaciaded area, 67%; Tipton till plain, 65%; Illinoian Drift area, 56%; Prairie area, 8%; Lower Wabash Valley area, 28%.

3. Forty-seven species are intraneous and occur in the following percentages: Lakes area, 83%; Tipton till plain, 85%; Illinoian Drift area, 75%; Unglaciaded area, 79%; Lower Wabash Valley area, 45%; Prairie area, 14%; all areas, 8%.

4. Twenty-seven species are extraneous, being on the limit of their ranges. The greatest number, 15 or 55%, of extraneous species is found in the Unglaciaded area and the Lakes area. Other areas with their percentages of extraneous species are as follows: Tipton till plain, 33%; Illinoian Drift area, 37%; Prairie area, 7%; Lower Wabash Valley area, 7%.

5. In considering the general distribution of the Pteridophyta found in Indiana, the greatest density of the species occurs in the Appalachian Highlands in which 84% of the species were recognized. The relative density of the Indiana Pteridophyta in the other physiographic divisions of the United States are as follows: the Interior Low Plateaus, 81%; Interior Highlands, 76%; Laurentian Uplands, 59%; Interior Plains, 48%; Atlantic Plains, 26%; Intermontane Plateaus, 11%; Pacific Mountain System, 8%; Rocky Mountain System, 7%.

6. Of the extraneous species, 92% have a range which extends in a northeast direction from Indiana. The percentages of the extraneous species which have their ranges in the other compass directions are as follows:—east, 68; south, 55; southwest, 58; west, 42; northwest, 42; north, 52.

## ACKNOWLEDGMENT

The writer wishes to express appreciation to Dr. Ray C. Friesner who suggested this topic and under whose direction the work was done.

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TABLE II

The Distribution of Pteridophyta within the Floral Areas of Indiana

P, Prairie Area; L, Lakes Area; T, Tipton Till Plain; I, Illinoian Drift Area; U, Unglaciaded Area; W, Lower Wabash Valley Area; E, SE, S, SW, W, NW, N, E, Compass directions in which distributions of extraneous species occur outside Indiana.

| Species                                        | P | L | T | I | U | W | Directions      |
|------------------------------------------------|---|---|---|---|---|---|-----------------|
| OPHIOGLOSSACEAE                                |   |   |   |   |   |   |                 |
| <i>Ophioglossum vulgatum</i>                   |   | X | X | X | X | X | (Intr.)         |
| <i>O. vulgatum</i> f. <i>pseudopodium</i>      |   | X |   |   |   |   | (Intr.)         |
| <i>O. engelmanni</i>                           |   |   |   |   | X |   | SE, S, SW       |
| <i>Botrychium simplex</i>                      |   | X |   |   |   |   | NW, N, NE       |
| <i>B. multifidum</i> var. <i>silaifolium</i>   |   | X |   |   |   |   | NW, N, NE       |
| <i>B. dissectum</i>                            |   | X | X | X | X | X | (Intr.)         |
| <i>B. dissectum</i> f. <i>elongatum</i> (15)   |   | X | X |   |   |   | W, NW, N, NE    |
| <i>B. dissectum</i> var. <i>obliquum</i>       |   | X | X | X | X | X | (Intr.)         |
| <i>B. dissectum</i> var. <i>tenuifolium</i>    |   |   |   |   | X |   | SE, S, SW       |
| <i>B. dissectum</i> var. <i>oneidense</i>      |   | X | X |   |   |   | W, NW, NE, E    |
| <i>B. virginianum</i>                          |   | X | X | X | X | X | (Intr.)         |
| OSMUNDACEAE                                    |   |   |   |   |   |   |                 |
| <i>Osmunda regalis</i> var. <i>spectabilis</i> |   | X | X | X | X | X | (Intr.)         |
| <i>O. claytonia</i>                            |   | X | X | X | X |   | (Intr.)         |
| <i>O. cinnamomea</i>                           |   | X | X | X | X | X | (Intr.)         |
| <i>O. cinnamomea</i> f. <i>auriculata</i>      |   | X |   |   |   |   | (Intr.)         |
| <i>O. cinnamomea</i> f. <i>frondosa</i>        |   | X |   |   |   |   | (Intr.)         |
| <i>O. cinnamomea</i> f. <i>incisa</i>          |   | X |   |   |   |   | (Intr.)         |
| POLYPODIACEAE                                  |   |   |   |   |   |   |                 |
| <i>Woodsia obtusa</i>                          |   | X | X | X | X | X | (Intr.)         |
| <i>Cystopteris bulbifera</i>                   |   | X | X | X | X | X | (Intr.)         |
| <i>C. fragilis</i>                             |   | X | X | X | X |   | (Intr.)         |
| <i>C. fragilis</i> var. <i>protrusa</i>        |   |   | X | X |   | X | (Intr.)         |
| <i>C. fragilis</i> var. <i>mackayii</i> (15)   |   |   | X |   |   |   | W, NW, N, NE, E |
| <i>Pteretis pensylvanica</i>                   |   | X | X | X | X |   | (Intr.)         |
| <i>P. pensylvanica</i> f. <i>pubescens</i>     |   | X | X |   |   |   | (Intr.)         |
| <i>Onoclea sensibilis</i>                      | X | X | X | X | X | X | (Intr.)         |
| <i>Dryopteris hexagonoptera</i>                |   | X | X | X | X |   | (Intr.)         |
| <i>D. noveboracensis</i>                       |   | X | X | X | X |   | (Intr.)         |
| <i>D. thelypteris</i> var. <i>pubescens</i>    | X | X | X | X | X |   | (Intr.)         |
| <i>D. marginalis</i>                           |   | X | X | X | X |   | (Intr.)         |
| <i>D. goldiana</i>                             |   | X | X | X | X |   | (Intr.)         |
| <i>D. goldiana</i> X <i>marginalis</i>         |   |   |   |   | X |   | —               |
| <i>D. cristata</i>                             |   | X | X |   | X |   | (Intr.)         |
| <i>D. cristata</i> var. <i>clintonia</i>       |   | X |   |   |   |   | —               |
| <i>D. cristata</i> X <i>spinulosa</i>          |   | X |   |   |   |   | —               |
| <i>D. spinulosa</i>                            |   | X | X | X | X |   | (Intr.)         |

TABLE II—(Continued)

The Distribution of Pteridophyta within the Floral Areas of Indiana

P, Prairie Area; L, Lakes Area; T, Tipton Till Plain; I, Illinoian Drift Area; U, Unglaciaded Area; W, Lower Wabash Valley Area; E, SE, S, SW, W, NW, N, E, Compass directions in which distributions of extraneous species occur outside Indiana.

| Species                                          | P | L | T | I | U | W | Directions          |
|--------------------------------------------------|---|---|---|---|---|---|---------------------|
| <i>D. spinulosa</i> var. <i>fructuosa</i>        |   | X |   |   |   |   | —                   |
| <i>D. intermedia</i>                             |   | X | X |   | X |   | (Intr.)             |
| <i>D. boottii</i>                                |   | X | X |   |   |   | (Intr.)             |
| <i>D. intermedia</i> X <i>marginalis</i> (15)    |   |   | X |   |   |   | —                   |
| <i>Polystichum acrostichoides</i>                |   | X | X | X | X | X | (Intr.)             |
| <i>P. acrostichoides</i> f. <i>incisum</i>       |   |   |   | X | X |   | (Intr.)             |
| <i>P. acrostichoides</i> f. <i>crispum</i>       |   | X |   |   |   |   | (Intr.)             |
| <i>Dennstaedtia punctilobula</i>                 |   |   | X |   | X | X | (Intr.)             |
| <i>Athyrium pycnocarpon</i>                      |   | X | X | X | X | X | (Intr.)             |
| <i>A. thelypteroides</i>                         |   | X | X | X | X |   | (Intr.)             |
| <i>A. asplenioides</i>                           |   | X | X | X | X | X | E, SE, S, SW, W, NE |
| <i>A. angustum</i>                               |   | X | X | X | X | X | (Intr.)             |
| <i>A. angustum</i> var. <i>elatus</i>            |   | X | X | X | X |   | (Intr.)             |
| <i>A. angustum</i> var. <i>rubellum</i>          |   | X | X | X | X | X | (Intr.)             |
| <i>Camptosorum rhizophyllum</i>                  |   |   | X | X | X | X | (Intr.)             |
| <i>C. rhizophyllum</i> f. <i>auriculatus</i>     |   |   |   |   | X |   |                     |
| <i>Asplenium cryptolepis</i>                     |   |   |   | X | X |   | NE, E, SE, S, SW    |
| <i>A. pinnatifidum</i>                           |   |   | X | X | X |   | NE, E, SE, S, SW    |
| <i>A. platyneuron</i>                            |   | X | X | X | X | X | (Intr.)             |
| <i>A. platyneuron</i> f. <i>serratum</i>         |   |   |   |   | X |   | NE, E, SE, S, SW    |
| <i>A. trichomanes</i>                            |   |   | X |   | X |   | (Intr.)             |
| <i>Asplenosorus ebenoides</i>                    |   |   |   | X | X |   | NE, E, SE, S, SW    |
| <i>Woodwardia virginica</i>                      |   | X |   |   |   |   | N, NE, E, SE, S     |
| <i>Pellaea atropurpurea</i>                      |   |   | X | X | X |   | (Intr.)             |
| <i>P. glabella</i>                               |   |   | X | X | X |   | NE, E, SE, S, SW, W |
| <i>Cheilanthes lanosa</i>                        |   |   |   |   | X |   | NE, E, SE, S, SW    |
| <i>Adiantum pedatum</i>                          |   | X | X | X | X | X | (Intr.)             |
| <i>Pteridium aquilinum</i> v. <i>latiusculum</i> | X | X | X | X | X | X | (Intr.)             |
| <i>P. aquilinum</i> var. <i>pseudocaudatum</i>   |   |   |   | X | X |   | NE, E, SE, S, SW    |
| <i>Polypodium virginianum</i>                    |   | X | X | X | X |   | (Intr.)             |
| <i>P. polypodioides</i> v. <i>michauxianum</i>   |   |   |   | X | X | X | E, SE, S, SW        |
| SALVINIACEAE                                     |   |   |   |   |   |   |                     |
| <i>Azolla caroliniana</i>                        |   | X | X | X |   | X | (Intr.)             |
| EQUISETACEAE                                     |   |   |   |   |   |   |                     |
| <i>Equisetum arvense</i>                         | X | X | X | X | X | X | (Intr.)             |
| <i>E. trachyodon</i>                             |   | X |   |   |   |   | —                   |
| <i>E. variegatus</i>                             |   | X |   |   |   |   | W, NW, N, NE        |
| <i>E. nelsoni</i>                                |   | X | X |   |   |   | NW, N               |

TABLE II—(Continued)

The Distribution of Pteridophyta within the Floral Areas of Indiana

P, Prairie Area; L, Lakes Area; T, Tipton Till Plain; I, Illinoian Drift Area; U, Unglaciaded Area; W, Lower Wabash Valley Area; E, SE, S, SW, W, NW, N, E, Compass directions in which distributions of extraneous species occur outside Indiana.

| Species                                     | P | L | T | I | U | W | Directions          |
|---------------------------------------------|---|---|---|---|---|---|---------------------|
| <i>E. prealtum</i>                          | X | X | X | X | X | X | (Intr.)             |
| <i>L. laevigatum</i>                        | X | X | X | X | X |   | SW, W, NW, N, NE    |
| <i>E. kansanum</i>                          | X | X | X | X |   |   | SW, W, N, NE        |
| <i>E. fluviatile</i>                        |   | X | X |   |   |   | W, NW, N, NE        |
| LYCOPIDIACEAE                               |   |   |   |   |   |   |                     |
| <i>Lycopodium selago</i> var. <i>patens</i> |   |   |   |   | X |   | NE, E, SE, S, SW, W |
| <i>L. lucidulum</i>                         |   | X | X | X | X |   | (Intr.)             |
| <i>L. inundatum</i>                         |   | X |   |   |   |   | W, NW, N, NE, E     |
| <i>L. obscurum</i>                          |   | X |   |   |   |   | NW, N, NE, E, SE    |
| <i>L. flabelliforme</i>                     |   | X | X | X | X |   | (Intr.)             |
| <i>L. tristachyum</i> (19)                  |   | X |   |   |   |   | NW, N, NE, E, SE    |
| SELAGINELLACEAE                             |   |   |   |   |   |   |                     |
| <i>Selaginella apoda</i>                    |   | X | X | X | X |   | (Intr.)             |
| <i>S. rupestris</i>                         |   | X | X |   |   |   | (Intr.)             |
| ISOETACEAE                                  |   |   |   |   |   |   |                     |
| <i>Isoetes engelmanni</i>                   |   |   |   |   | X |   | NE, E, SE, S, SW    |

TABLE III

The Distribution of Intraneous and Extraneous Species in the Floral Areas of Indiana

| Botanical Areas      | <i>Intraneous</i> |         | <i>Extraneous</i> |         | <i>Totals</i>  |         |
|----------------------|-------------------|---------|-------------------|---------|----------------|---------|
|                      | No. of Species    | Percent | No. of Species    | Percent | No. of Species | Percent |
| Lakes Area           | 41                | 83      | 15                | 55      | 62             | 74      |
| Prairie Area         | 7                 | 14      | 2                 | 7       | 7              | 8       |
| Tipton Till Plain    | 42                | 85      | 9                 | 33      | 55             | 65      |
| Illinoian Drift Area | 37                | 75      | 10                | 37      | 47             | 56      |
| Unglaciaded Area     | 39                | 79      | 15                | 55      | 56             | 67      |
| Wabash Valley Area   | 22                | 45      | 2                 | 7       | 24             | 28      |
| In all areas         | 4                 | 8       | 0                 | 0       | 4              | 5       |
| Entire state         | 49                | 100     | 27                | 100     | 84             | 100     |

# GROWTH DATA FROM NINE SECTIONS OF ACER SACCHARUM FROM MONTGOMERY COUNTY, INDIANA

By CHESTER W. MILLER

Nine sections of *Acer saccharum* were cut in 1940, following logging operations on the Albert Smith farm 13 miles southwest of Crawfordsville and about 3 miles east of Alamo, Indiana. Rainfall data were secured from the U. S. Weather Bureau Station which is located at Crawfordsville approximately 13 miles northeast from the forest in which the trees grew. Unfortunately, the rainfall data are not complete from 1884 through 1910; consequently, no growth-rainfall correlation could be determined for those years. Rainfall behavior charts were prepared for the rainfall periods May-August, May-June, May-July, June-July and June-August (1).

Growth as shown by annual-ring width was measured along three radii of each section. Measurements were made under a 10X magnifier and to the nearest quarter millimeter. Growth behavior charts were prepared from the sums of the measurements of the three radii for each section individually. Fuller (2) used the averages of three radii in his work with oak in Illinois. In a previous paper (3) dealing with three deciduous species of trees from Brown County, Indiana, the sums of the measurements of four radii were used.

Tables are presented, showing the average yearly growth (in millimeters) for each of the nine sections of *Acer saccharum* and growth-rainfall trend coefficients (4) i.e., the percentage of agreement in sign of the year to year changes between rainfall and growth, for the different rainfall periods.

## OBSERVATION

The average yearly radial growth of the 9 sections is shown in table I. It may be noted that the oldest section, 40A-12, gives growth data back to and including 1710. These total data are presented because they cover a longer period of time than has been reported in any previous Indiana studies.

Growth-rainfall trend coefficients for the different month combinations are shown in table II. *Acer saccharum* shows its highest trend coefficient in the present study for the rainfall period June-July. This indicates that annual radial growth in this area is more sensitive to rainfall changes during the early summer months. Friesner (1) found the highest trend coefficient for this species to occur during the rainfall period May-August. This was on sites with considerable relief and hence subject to excessive run-off.

## SUMMARY AND CONCLUSIONS

1. Annular-ring growth data of *Acer saccharum* is given to and including the year 1710.

2. In the present study, the highest growth-rainfall trend coefficient is shown for the rainfall period June-July.

## LITERATURE CITED

1. FRIESNER, RAY C. Growth-rainfall trend coefficients shown by six species of hardwoods in Brown County, Indiana. *Butler Univ. Bot. Stu.* 9(14). 1950.
2. FULLER, GEORGE D. Growth rings of the red oak as related to precipitation in Illinois. *Illinois St. Acad. Sci. Trans.* 31:102-104. 1938.
3. MILLER, CHESTER W. The effect of precipitation on the annular-ring growth in three species of trees from Brown County, Indiana. *Butler Univ. Bot. Stud.* 9(17). 1950.
4. SCHULMAN, W. J. Dendrochronology at Navajo National Monument. *Tree-Ring Bul.* 14:18-24. 1948.

TABLE I

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1940 | 0.4mm          | 1.1mm | 3.2mm | 1.5mm | 2.6mm | 1.7mm | 1.3mm | 1.6mm  | 0.7mm  |
| 1939 | 0.4            | 1.4   | 2.0   | 1.7   | 3.7   | 2.0   | 1.4   | 2.6    | 1.2    |
| 1938 | 0.4            | 1.0   | 2.0   | 1.4   | 0.6   | 2.3   | 1.1   | 4.0    | 0.9    |
| 1937 | 0.3            | 0.6   | 3.6   | 1.1   | 3.1   | 1.3   | 0.6   | 2.6    | 1.2    |
| 1936 | 0.5            | 0.7   | 2.6   | 1.0   | 1.9   | 0.8   | 0.2   | 1.2    | 1.5    |
| 1935 | 0.6            | 1.3   | 1.3   | 2.0   | 1.6   | 1.2   | 1.0   | 1.7    | 1.9    |
| 1934 | 0.5            | 0.6   | 3.5   | 1.6   | 2.1   | 0.5   | 0.3   | 1.3    | 1.8    |
| 1933 | 0.8            | 0.4   | 3.0   | 1.4   | 0.8   | 1.1   | 0.9   | 1.7    | 1.0    |
| 1932 | 0.6            | 0.4   | 1.6   | 2.1   | 1.2   | 1.6   | 1.1   | 3.6    | 1.5    |
| 1931 | 0.4            | 0.8   | 1.3   | 1.1   | 3.1   | 0.6   | 0.6   | 2.8    | 1.9    |
| 1930 | 0.5            | 3.0   | 2.7   | 1.0   | 0.9   | 1.0   | 1.1   | 2.2    | 1.8    |
| 1929 | 0.6            | 4.8   | 2.6   | 1.0   | 2.1   | 1.6   | 1.6   | 3.3    | 0.6    |

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1928 | 0.8            | 2.8   | 2.4   | 1.5   | 2.6   | 2.1   | 3.0   | 3.4    | 1.2    |
| 1927 | 1.0            | 2.5   | 2.1   | 1.0   | 3.6   | 1.3   | 2.5   | 2.9    | 1.6    |
| 1926 | 1.0            | 3.3   | 2.2   | 1.0   | 2.1   | 1.1   | 1.5   | 2.7    | 1.9    |
| 1925 | 1.4            | 2.6   | 3.5   | 1.1   | 1.2   | 1.5   | 2.1   | 1.2    | 1.2    |
| 1924 | 0.6            | 2.9   | 3.1   | 1.0   | 0.8   | 1.7   | 2.1   | 1.4    | 0.7    |
| 1923 | 1.2            | 1.3   | 0.9   | 0.8   | 0.9   | 1.0   | 0.7   | 1.5    | 1.0    |
| 1922 | 0.9            | 4.1   | 2.1   | 0.6   | 0.3   | 1.0   | 0.4   | 2.0    | 1.2    |
| 1921 | 1.0            | 2.2   | 2.3   | 0.7   | 0.5   | 0.9   | 0.8   | 1.6    | 0.9    |
| 1920 | 1.4            | 2.9   | 1.3   | 0.6   | 1.6   | 1.1   | 0.8   | 1.5    | 0.6    |
| 1919 | 2.7            | 2.5   | 1.7   | 0.8   | 1.7   | 0.8   | 0.7   | 1.4    | 0.9    |
| 1918 | 1.8            | 1.5   | 1.7   | 0.5   | 1.4   | 1.1   | 0.6   | 2.1    | 1.2    |
| 1917 | 2.0            | 3.5   | 2.0   | 0.9   | 0.8   | 1.7   | 1.1   | 2.6    | 1.2    |
| 1916 | 2.3            | 3.0   | 2.1   | 1.1   | 0.9   | 2.1   | 1.6   | 1.8    | 1.1    |
| 1915 | 3.1            | 0.8   | 2.1   | 0.4   | 1.3   | 1.6   | 1.4   | 1.8    | 0.9    |
| 1914 | 1.5            | 1.7   | 2.6   | 0.7   | 1.7   | 0.7   | 0.4   | 2.8    | 1.6    |
| 1913 | 2.5            | 2.7   | 2.0   | 1.0   | 0.8   | 1.0   | 1.0   | 1.9    | 2.0    |
| 1912 | 4.6            | 2.4   | 1.5   | 1.1   | 1.4   | 1.6   | 1.0   | 3.2    | 2.1    |
| 1911 | 1.6            | 2.8   | 1.3   | 1.0   | 1.7   | 1.0   | 0.8   | 3.1    | 2.8    |
| 1910 | 4.3            | 3.0   | 1.7   | 1.2   | 1.0   | 1.3   | 1.1   | 3.3    | 2.9    |
| 1909 | 4.8            | 5.1   | 2.5   | 1.1   | 1.9   | 1.1   | 1.4   | 3.2    | 3.1    |
| 1908 | 3.8            | 4.7   | 2.1   | 1.5   | 2.1   | 1.9   | 1.4   | 1.2    | 1.8    |
| 1907 | 4.7            | 6.2   | 1.6   | 1.5   | 2.3   | 2.7   | 1.6   | 1.2    | 2.6    |
| 1906 | 4.1            | 6.6   | 2.1   | 1.5   | 2.3   | 2.5   | 1.7   | 2.1    | 3.5    |
| 1905 | 4.1            | 4.4   | 2.8   | 2.0   | 2.0   | 3.1   | 2.1   | 1.7    | 3.7    |
| 1904 | 4.3            | 4.5   | 2.6   | 1.9   | 2.3   | 2.8   | 2.1   | 2.2    | 3.6    |
| 1903 | 4.2            | 2.1   | 1.8   | 2.0   | 2.9   | 2.1   | 1.6   | 2.1    | 4.3    |
| 1902 | 4.5            | 2.5   | 0.5   | 1.6   | 2.6   | 3.1   | 1.6   | 1.4    | 4.5    |
| 1901 | 3.4            | 2.7   | 0.7   | 1.9   | 2.4   | 2.1   | 1.7   | 2.4    | 2.4    |
| 1900 | 4.4            | 2.3   | 0.5   | 1.6   | 2.5   | 2.1   | 1.3   | 2.5    | 2.6    |
| 1899 | 5.1            | 2.1   | 0.5   | 2.1   | 3.3   | 2.4   | 1.6   | 2.7    | 3.1    |
| 1898 | 4.8            | 2.3   | 0.5   | 3.2   | 2.7   | 2.2   | 1.1   | 2.5    | 3.7    |
| 1897 | 2.8            | 2.3   | 0.5   | 3.5   | 2.8   | 2.4   | 1.6   | 3.2    | 3.6    |
| 1896 | 5.1            | 2.1   | 0.7   | 4.6   | 2.7   | 3.6   | 1.2   | 1.7    | 4.0    |
| 1895 | 2.7            | 1.9   | 0.5   | 2.0   | 2.8   | 1.2   | 0.5   | 2.5    | 3.4    |
| 1894 | 3.8            | 0.8   | 0.2   | 2.6   | 1.3   | 2.4   | 0.8   | 2.2    | 2.1    |
| 1893 | 1.9            | 0.9   | 0.2   | 2.2   | 2.6   | 2.0   | 1.2   | 2.6    | 2.7    |
| 1892 | 2.8            | 0.7   | 0.2   | 4.5   | 1.7   | 2.8   | 1.0   | 1.9    | 3.9    |
| 1891 | 2.8            | 2.0   | 0.2   | 3.2   | 2.3   | 1.5   | 0.8   | 3.5    | 4.2    |
| 1890 | 2.1            | 2.2   | 0.5   | 4.8   | 2.0   | 1.1   | 1.4   | 7.8    | 4.3    |
| 1889 | 2.1            | 0.6   | 0.2   | 5.3   | 2.9   | 1.6   | 1.5   | 4.4    | 3.5    |
| 1888 | 2.1            | 1.5   | 0.5   | 3.6   | 4.2   | 1.2   | 0.5   | 4.4    | 2.6    |
| 1887 | 2.3            | 2.2   | 0.2   | 2.7   | 2.8   | 1.2   | 0.7   | 8.0    | 3.5    |

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1886 | 1.6            | 2.6   | 0.2   | 4.3   | 2.6   | 2.6   | 1.0   | 7.6    | 3.6    |
| 1885 |                | 1.4   | 0.5   | 4.0   | 3.5   | 2.4   | 1.2   | 9.0    | 2.3    |
| 1884 |                | 0.5   | 0.5   | 3.9   | 3.5   | 2.4   | 1.1   | 7.6    | 1.1    |
| 1883 |                | 0.6   | 0.5   | 3.2   | 4.4   | 2.2   | 0.8   | 5.5    | 1.2    |
| 1882 |                | 0.8   | 0.5   | 2.2   | 2.8   | 2.2   | 0.3   | 4.9    | 1.6    |
| 1881 |                | 0.9   | 0.5   | 1.6   | 1.6   | 2.3   | 0.4   | 6.5    | 2.2    |
| 1880 |                | 0.6   | 0.5   | 1.5   | 1.2   | 2.3   | 0.2   | 4.5    | 2.7    |
| 1879 |                | 1.2   | 0.2   | 1.1   | 2.3   | 1.2   | 0.8   | 6.2    | 0.7    |
| 1878 |                | 1.7   | 0.5   | 1.0   | 1.6   | 1.5   | 0.3   | 5.1    | 0.5    |
| 1877 |                | 1.7   | 0.2   | 1.5   | 2.1   | 3.1   | 0.3   | 6.4    | 0.7    |
| 1876 |                | 1.1   | 0.5   | 1.6   | 2.1   | 3.5   | 0.6   | 2.6    | 0.5    |
| 1875 |                | 1.4   | 0.2   | 1.6   | 2.2   | 1.5   | 0.6   | 2.2    | 0.5    |
| 1874 |                | 2.1   | 0.7   | 1.3   | 2.0   | 1.5   | 0.6   | 2.1    | 0.5    |
| 1873 |                | 0.6   | 0.2   | 2.1   | 1.4   | 0.6   | 0.8   | 2.4    | 0.5    |
| 1872 |                | 0.5   | 0.2   | 2.7   | 1.1   | 0.8   | 0.4   | 0.8    | 0.5    |
| 1871 |                | 0.6   | 0.7   | 5.1   | 1.1   | 0.6   | 0.6   | 0.9    | 1.3    |
| 1870 |                | 1.4   | 1.0   | 0.2   | 0.8   | 0.7   | 0.9   | 2.2    | 1.7    |
| 1869 |                | 1.0   | 1.0   | 0.2   | 0.9   | 1.0   | 0.4   | 0.6    | 2.8    |
| 1868 |                | 1.2   | 0.5   | 0.2   | 1.2   | 0.5   | 0.6   | 1.1    | 3.3    |
| 1867 |                | 1.3   | 0.2   | 0.2   | 0.0   | 0.5   | 0.7   | 1.1    | 5.1    |
| 1866 |                | 1.0   | 0.2   | 0.2   | 1.2   | 0.7   | 1.0   | 1.0    | 10.0*  |
| 1865 |                | 1.3   | 0.5   | 0.5   | 1.6   | 0.6   | 0.9   | 1.6    | 1.1    |
| 1864 |                | 2.7   | 0.5   | 0.7   | 1.1   | 0.8   | 0.6   | 2.1    | 0.6    |
| 1863 |                | 2.0   | 0.5   | 0.5   | 1.5   | 0.7   | 0.6   | 3.1    | 0.8    |
| 1862 |                | 2.3   | 0.7   | 1.0   | 2.2   | 0.8   | 0.7   | 4.6    | 0.5    |
| 1861 |                | 2.8   | 0.5   | 0.7   | 3.1   | 1.3   | 0.8   | 10.4*  | 0.5    |
| 1860 |                |       | 1.0   | 1.0   | 3.6   |       | 1.1   | 0.6    | 0.8    |
| 1859 |                |       | 1.3   | 0.5   | 5.0   |       | 0.6   | 0.5    | 0.5    |
| 1858 |                |       | 1.3   | 0.5   | 1.0   |       | 0.6   | 0.9    | 0.4    |
| 1857 |                |       | 1.2   | 0.7   | 0.4   |       | 0.8   | 0.9    | 0.4    |
| 1856 |                |       | 1.3   | 1.5   | 1.0   |       | 1.2   | 0.4    | 0.5    |
| 1855 |                |       | 1.2   | 1.0   | 0.5   |       | 0.9   | 0.9    | 0.9    |

\* These measurements were for the first year following cessation of removal of sap for syrup-making, as evidenced by the "overgrowing" of pile-holes in these two sections. It is to be noted that these "excessive" year-ring widths climax long periods of small amounts of growth and that they are followed by much higher annual radial growth than occurred during the earlier years when, presumably, sap was being removed annually. It is probable that the other seven sections also have a sap-removal history though no pile holes were encountered when the sections were cut from the tops of stumps left by logging operations.

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1854 |                |       | 0.9   | 1.1   | 0.3   |       | 0.9   | 0.6    | 0.5    |
| 1853 |                |       | 1.0   | 0.5   | 0.5   |       | 0.7   | 0.8    | 0.1    |
| 1852 |                |       | 1.0   | 0.5   | 0.3   |       | 0.4   | 1.0    | 0.9    |
| 1851 |                |       | 1.5   | 0.5   | 0.6   |       | 0.8   | 0.8    | 1.6    |
| 1850 |                |       | 1.5   | 0.5   | 0.5   |       | 0.4   | 0.9    | 2.2    |
| 1849 |                |       | 1.9   | 0.5   | 0.7   |       | 0.6   | 1.0    | 1.0    |
| 1848 |                |       | 0.6   | 0.9   | 0.6   |       | 0.9   | 1.0    | 0.6    |
| 1847 |                |       | 2.1   | 0.8   | 0.6   |       | 0.7   | 0.9    | 1.1    |
| 1846 |                |       | 1.9   | 0.9   | 0.6   |       | 1.5   | 0.9    | 2.0    |
| 1845 |                |       | 1.8   | 1.8   | 0.6   |       | 0.9   | 0.6    | 1.8    |
| 1844 |                |       | 1.9   | 1.0   | 0.7   |       | 1.1   | 0.8    | 1.2    |
| 1843 |                |       | 1.6   | 0.8   | 0.6   |       | 1.1   | 0.9    | 2.0    |
| 1842 |                |       | 1.5   | 0.9   | 0.9   |       | 1.8   | 1.0    | 2.1    |
| 1841 |                |       | 1.6   | 0.8   | 0.9   |       | 1.0   | 0.9    | 1.9    |
| 1840 |                |       | 1.7   | 1.1   | 1.1   |       | 1.3   | 1.0    | 2.9    |
| 1839 |                |       | 2.5   | 0.7   | 1.0   |       | 1.9   | 0.8    | 3.5    |
| 1838 |                |       | 2.0   | 0.8   | 1.0   |       | 2.1   | 0.8    | 1.5    |
| 1837 |                |       | 1.6   | 1.0   | 1.4   |       | 2.2   | 1.2    | 1.1    |
| 1836 |                |       | 2.3   | 0.9   | 1.2   |       | 2.1   | 1.2    | 1.9    |
| 1835 |                |       | 1.8   | 1.7   | 1.0   |       | 2.1   | 0.8    | 1.4    |
| 1834 |                |       | 1.9   | 1.6   | 1.2   |       | 1.6   | 1.0    | 1.1    |
| 1833 |                |       | 1.1   | 1.1   | 1.3   |       | 1.3   | 0.9    | 0.6    |
| 1832 |                |       | 0.9   | 0.6   | 1.0   |       | 1.9   | 1.4    | 0.9    |
| 1831 |                |       | 1.1   | 0.9   | 0.8   |       | 2.2   | 1.4    | 1.6    |
| 1930 |                |       | 1.2   | 0.6   | 1.1   |       | 2.1   | 1.4    | 1.5    |
| 1829 |                |       | 1.1   | 0.9   | 1.0   |       | 2.0   | 0.6    | 2.3    |
| 1828 |                |       | 1.5   | 0.6   | 1.0   |       | 1.5   | 0.8    | 0.7    |
| 1827 |                |       | 1.6   | 0.7   | 0.5   |       | 1.9   | 1.1    | 1.3    |
| 1826 |                |       | 1.6   | 1.1   | 1.2   |       | 2.1   | 1.5    | 1.1    |
| 1825 |                |       | 2.1   | 1.0   | 1.0   |       | 2.4   | 1.8    | 1.3    |
| 1824 |                |       | 2.1   | 0.8   | 1.2   |       | 2.1   | 2.4    | 2.0    |
| 1823 |                |       | 1.5   | 0.8   | 1.1   |       | 2.8   | 1.4    | 2.4    |
| 1822 |                |       | 1.4   | 1.1   | 0.9   |       | 2.6   | 1.2    | 1.9    |
| 1821 |                |       | 1.5   | 1.0   | 0.6   |       | 2.5   | 2.1    | 2.2    |
| 1820 |                |       | 1.1   | 0.9   | 1.0   |       | 2.3   | 2.5    | 3.0    |
| 1819 |                |       | 1.4   | 1.4   | 1.0   |       | 2.7   | 1.8    | 2.5    |
| 1818 |                |       | 1.9   | 1.3   | 1.1   |       | 2.4   | 1.8    | 2.6    |
| 1817 |                |       | 0.7   | 1.4   | 1.6   |       | 1.9   | 2.5    | 2.8    |
| 1816 |                |       | 1.1   | 1.3   | 1.1   |       | 2.2   | 2.0    | 3.6    |
| 1815 |                |       | 1.6   | 1.2   | 0.8   |       | 2.3   | 2.2    | 3.6    |
| 1814 |                |       | 1.1   | 1.6   | 1.0   |       | 2.1   | 1.5    | 2.8    |
| 1813 |                |       | 1.7   | 1.6   | 1.9   |       | 1.9   | 1.0    | 0.9    |

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1812 |                |       | 1.4   | 1.5   | 1.4   |       | 2.9   | 1.4    | 0.7    |
| 1811 |                |       | 1.4   | 2.4   | 1.4   |       | 2.3   | 1.2    | 1.0    |
| 1810 |                |       | 1.5   | 2.6   | 1.6   |       | 1.7   | 1.5    | 1.5    |
| 1809 |                |       | 2.0   | 1.6   | 1.1   |       | 1.9   | 2.2    | 2.1    |
| 1808 |                |       | 1.7   | 1.6   | 1.1   |       |       | 1.2    | 1.6    |
| 1807 |                |       | 1.1   | 0.9   | 0.7   |       |       | 1.0    | 1.1    |
| 1806 |                |       | 1.2   | 1.3   | 1.1   |       |       | 1.2    | 2.2    |
| 1805 |                |       | 1.7   | 1.1   | 1.3   |       |       | 1.8    | 1.6    |
| 1804 |                |       | 1.3   | 1.3   | 1.2   |       |       | 1.5    | 1.1    |
| 1803 |                |       | 1.3   | 1.6   | 1.3   |       |       | 2.2    | 1.8    |
| 1802 |                |       | 1.7   | 1.0   | 1.4   |       |       | 2.0    | 1.6    |
| 1801 |                |       | 1.9   | 1.5   | 0.9   |       |       | 1.6    | 1.5    |
| 1800 |                |       | 1.8   | 1.0   | 1.0   |       |       | 1.5    | 1.6    |
| 1799 |                |       | 1.6   | 2.2   | 1.1   |       |       | 1.2    | 2.1    |
| 1798 |                |       | 1.6   | 2.5   | 1.3   |       |       | 1.6    | 1.6    |
| 1797 |                |       | 1.5   | 2.0   | 1.6   |       |       | 2.2    | 0.9    |
| 1796 |                |       | 1.2   | 1.7   | 1.1   |       |       | 2.5    | 2.2    |
| 1795 |                |       | 1.0   | 1.6   | 1.3   |       |       | 2.6    | 1.7    |
| 1794 |                |       | 1.5   | 2.0   | 1.3   |       |       | 1.9    | 2.1    |
| 1793 |                |       | 1.2   | 2.1   | 1.2   |       |       | 2.4    | 1.6    |
| 1792 |                |       | 2.1   | 1.8   | 0.6   |       |       | 1.6    | 2.3    |
| 1791 |                |       | 1.5   | 3.4   | 1.1   |       |       | 1.5    | 1.1    |
| 1790 |                |       | 2.0   | 1.6   | 1.5   |       |       | 1.9    | 0.8    |
| 1789 |                |       | 1.7   | 3.1   | 1.3   |       |       | 1.2    | 1.1    |
| 1788 |                |       | 2.3   | 3.5   | 1.7   |       |       | 1.0    | 1.3    |
| 1787 |                |       | 1.8   | 1.8   | 1.1   |       |       | 1.6    | 1.5    |
| 1786 |                |       | 2.1   | 2.0   | 1.7   |       |       | 1.5    | 1.9    |
| 1785 |                |       | 1.3   | 2.1   | 1.1   |       |       | 0.9    | 2.1    |
| 1784 |                |       | 1.5   | 1.1   | 1.1   |       |       | 0.9    |        |
| 1783 |                |       | 1.1   | 2.1   | 1.6   |       |       | 1.0    |        |
| 1782 |                |       | 2.1   | 1.6   | 1.2   |       |       | 1.7    |        |
| 1781 |                |       | 1.6   | 1.5   | 1.1   |       |       | 0.7    |        |
| 1780 |                |       | 1.9   | 1.9   | 1.2   |       |       | 1.2    |        |
| 1779 |                |       | 1.7   | 1.6   | 1.4   |       |       | 0.9    |        |
| 1778 |                |       | 1.9   | 1.6   | 1.1   |       |       | 1.5    |        |
| 1777 |                |       | 2.1   | 1.7   | 1.0   |       |       | 1.0    |        |
| 1776 |                |       | 2.1   | 1.1   | 1.4   |       |       | 1.5    |        |
| 1775 |                |       |       | 1.5   | 1.4   |       |       | 1.6    |        |
| 1774 |                |       |       | 1.6   | 1.0   |       |       | 0.7    |        |
| 1773 |                |       |       | 1.8   | 1.3   |       |       | 1.5    |        |
| 1772 |                |       |       | 1.0   | 0.8   |       |       | 1.2    |        |
| 1771 |                |       |       | 1.6   | 1.1   |       |       | 1.0    |        |

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1770 |                |       |       | 1.5   | 1.2   |       |       | 1.7    |        |
| 1769 |                |       |       | 1.0   | 1.1   |       |       | 1.0    |        |
| 1768 |                |       |       | 2.2   | 1.9   |       |       | 1.6    |        |
| 1767 |                |       |       | 1.0   | 1.5   |       |       | 1.1    |        |
| 1766 |                |       |       | 1.2   | 1.6   |       |       | 1.4    |        |
| 1765 |                |       |       | 0.7   | 1.4   |       |       | 1.4    |        |
| 1764 |                |       |       | 1.0   | 1.2   |       |       | 1.1    |        |
| 1763 |                |       |       | 1.4   | 1.9   |       |       | 1.9    |        |
| 1762 |                |       |       | 0.6   | 3.1   |       |       | 1.2    |        |
| 1761 |                |       |       | 1.1   | 1.7   |       |       | 2.0    |        |
| 1760 |                |       |       | 0.8   | 1.6   |       |       | 1.0    |        |
| 1759 |                |       |       | 1.0   | 1.7   |       |       | 0.7    |        |
| 1758 |                |       |       | 1.0   | 1.8   |       |       | 1.0    |        |
| 1757 |                |       |       | 1.0   | 1.2   |       |       | 1.2    |        |
| 1756 |                |       |       | 1.5   | 1.9   |       |       | 1.0    |        |
| 1755 |                |       |       | 1.0   | 1.4   |       |       | 1.7    |        |
| 1754 |                |       |       | 1.6   | 2.0   |       |       | 1.5    |        |
| 1753 |                |       |       | 1.0   | 1.3   |       |       | 1.6    |        |
| 1752 |                |       |       | 1.0   | 1.3   |       |       | 1.6    |        |
| 1751 |                |       |       | 0.8   | 1.5   |       |       | 1.5    |        |
| 1750 |                |       |       | 1.1   | 1.3   |       |       | 2.0    |        |
| 1749 |                |       |       | 0.7   | 1.3   |       |       | 1.5    |        |
| 1748 |                |       |       | 1.0   | 1.6   |       |       | 2.4    |        |
| 1747 |                |       |       | 1.0   | 1.1   |       |       | 1.5    |        |
| 1746 |                |       |       | 1.1   | 1.4   |       |       | 1.9    |        |
| 1745 |                |       |       | 0.9   | 1.8   |       |       | 1.6    |        |
| 1744 |                |       |       | 0.6   | 1.9   |       |       | 2.0    |        |
| 1743 |                |       |       | 0.5   | 2.0   |       |       | 1.0    |        |
| 1742 |                |       |       | 0.5   | 1.6   |       |       | 1.9    |        |
| 1741 |                |       |       | 0.9   | 1.3   |       |       | 1.1    |        |
| 1740 |                |       |       | 0.6   | 2.1   |       |       | 1.1    |        |
| 1739 |                |       |       | 0.6   | 2.2   |       |       | 1.6    |        |
| 1738 |                |       |       | 0.8   | 2.1   |       |       | 1.5    |        |
| 1737 |                |       |       | 0.4   | 1.8   |       |       | 0.7    |        |
| 1736 |                |       |       | 0.4   | 1.4   |       |       | 1.5    |        |
| 1935 |                |       |       | 0.4   | 1.4   |       |       | 1.0    |        |
| 1734 |                |       |       | 0.4   | 1.4   |       |       | 0.7    |        |
| 1733 |                |       |       | 0.6   | 1.6   |       |       | 1.6    |        |
| 1732 |                |       |       | 0.4   | 1.1   |       |       | 1.4    |        |
| 1731 |                |       |       | 0.3   | 1.0   |       |       | 1.4    |        |
| 1730 |                |       |       | 0.5   | 1.9   |       |       | 0.9    |        |
| 1729 |                |       |       | 0.6   | 1.4   |       |       | 1.0    |        |

TABLE I—(Continued)

Showing the average annual radial growth of nine sections of *Acer saccharum*

| Year | Section Number |       |       |       |       |       |       |        |        |
|------|----------------|-------|-------|-------|-------|-------|-------|--------|--------|
|      | 40A-2          | 40A-4 | 40A-5 | 40A-6 | 40A-7 | 40A-8 | 40A-9 | 40A-12 | 40A-13 |
| 1728 |                |       |       | 0.5   | 1.4   |       |       | 1.2    |        |
| 1727 |                |       |       | 0.5   | 1.0   |       |       | 1.4    |        |
| 1726 |                |       |       | 0.5   | 1.2   |       |       | 0.9    |        |
| 1725 |                |       |       | 0.4   |       |       |       | 0.6    |        |
| 1724 |                |       |       | 0.6   |       |       |       | 0.9    |        |
| 1723 |                |       |       | 0.6   |       |       |       | 0.6    |        |
| 1722 |                |       |       | 0.7   |       |       |       | 0.5    |        |
| 1721 |                |       |       | 0.8   |       |       |       | 0.6    |        |
| 1720 |                |       |       | 1.0   |       |       |       | 0.6    |        |
| 1719 |                |       |       | 1.2   |       |       |       | 0.6    |        |
| 1718 |                |       |       | 1.3   |       |       |       | 0.6    |        |
| 1717 |                |       |       | 1.2   |       |       |       | 0.6    |        |
| 1716 |                |       |       | 1.0   |       |       |       | 0.5    |        |
| 1715 |                |       |       |       |       |       |       | 0.5    |        |
| 1714 |                |       |       |       |       |       |       | 0.7    |        |
| 1713 |                |       |       |       |       |       |       | 1.0    |        |
| 1712 |                |       |       |       |       |       |       | 0.9    |        |
| 1711 |                |       |       |       |       |       |       | 0.9    |        |
| 1710 |                |       |       |       |       |       |       | 1.0    |        |

TABLE II

Trend coefficients of *Acer saccharum* for each month-combination rainfall period

| Month Combination |            | Trend Coefficient |
|-------------------|------------|-------------------|
| June-July         | (2 months) | 63                |
| June-August       | (3 months) | 60                |
| May-August        | (4 months) | 57                |
| May-July          | (3 months) | 57                |
| May-June          | (2 months) | 51                |

# FOREST SUCCESSION IN THE VALPARAISO AND PACKERTON MORAINES IN INDIANA<sup>1</sup>

By JOHN L. OLIVER

Indiana has experienced many climatic changes due primarily to its geographical location which brought it in contact with climates which find expression in boreal, grassland, and the southern deciduous forest vegetations. Many of the vegetational changes we will perhaps never be able to reconstruct for lack of fossil records. The more recent of these climatic changes, however, left their imprint on known records of forest history and on present-day plant distribution in Indiana. For the northern half of the state, pollen studies reconstruct remarkably well even the fluctuations of great formations and the climatic succession of formations and associations.

From present-day vegetation it might be assumed that the history of western Indiana vegetation differs from that of eastern and central Indiana vegetation. This possibility prompted the present study. Moderating climate replaced a simple forest with a complex association of species in which physiography began to play a part in selection of genera and species. The Indiana vegetation of today therefore shows both climatic and physiographic controls. The botanical areas as defined by Deam (1) are, geologically speaking, a comparatively recent development, as clearly revealed by fossil pollens in sediments which accumulated during post-glacial times.

Some of the greatest modifications and replacements in Indiana vegetation occurred when continental ice sheets moved southward and covered most of the state. As the melting ice sheets withdrew, the dark spruce forests entered upon the stage, only to build a better soil which, combined with a moderating climate, favored invasion by the taller pines. They in turn were replaced by the broad-leaved species.

When civilized man came to Indiana, much of this drama had been packed into the deepening layers of soil. Pollen analysis is a method of searching the ruins for records of that drama, and every profile

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<sup>1</sup> A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

adds to the unfolding picture of migrating forests which bogs already analyzed have presented to us. Potzger (8) calls them "phantom forests which live again in the pollen records."

The two pollen profiles presented here, one from Leroy Bog, Lake County, in the Valparaiso Moraine, the other from Shoe Lake, Kosciusko County, in the Packerton Moraine, show that progress of past vegetation was not the same in the northwestern corner of Indiana as in the north-central portion of the state.

Indiana was subjected to three distinct glacial periods: The Illinoian, the Early Wisconsin, and the Late Wisconsin glaciations. In the northern one-third of the state, the Late Wisconsin glacier left as physiographic features several series of morainic systems. Two morainic systems, probably terminal moraines, are involved in the present study. The retreat of the glacier also left many lakes, some of which remain today, although considerably diminished in size, the others having been filled in completely by deposition of plant remains. Leroy bog is an example of the latter while Shoe Lake, of about the same depth, is not yet completely filled in.

## PHYSIOGRAPHY OF AREAS INVESTIGATED

While both Leroy bog and Shoe Lake are in the Late Wisconsin glaciation, they are in different morainic systems (Malott, 7). Leroy bog lies within the Valparaiso Morainic system which swings around the southern end of Lake Michigan and extends into lower Michigan. It seems also to have been the southern boundary of old Lake Chicago. It belongs to the morainic system of the Lake Michigan lobe of Late Wisconsin Cary Substage. The bog is located two miles southeast of Leroy and northeast of Crown Point, Indiana. It is of the valley type with a combination of gentle and steep slopes surrounding it.

The Packerton Moraine in which Shoe Lake is located belongs to the moraines of the Saginaw lobe of late Wisconsin Substage. It has its origin in northern Carroll County, extends northeastward through Cass, Miami, Fulton, Kosciusko, and Whitley Counties, and terminates about the middle of Noble County. Here it joins with the Morainic system of the Erie Lobe. Shoe Lake is two miles southeast of Oswego, Indiana, and one mile south of the eastern end of Tippecanoe Lake.

## METHODS

The Hiller-type borer was used to collect the samples in the Leroy bog. Several trial borings were made in an attempt to find the deepest place in the basin which, as shown by Potzger (9); and Potzger and Wilson (11), is essential to assure a complete profile, since lakes begin filling in the deepest parts of their basins. For the samples at Shoe Lake, I am indebted to Dr. Ira T. Wilson and co-workers who collected the samples according to the method described by Wilson (14).

The laboratory technique employed was essentially the same as that described by Geisler (3). Some experimentation with stains was made. Crystal violet in clove oil was found to stain the pollen grains much more consistently than the aqueous solution of crystal violet. A small amount of safranin was also added to provide a contrast in the materials with which the pollens were associated. This combination rendered the pollen grains easily distinguishable from animal cysts, fern spores, and other plant remains. The aqueous solution of crystal violet seemed to have no effect on the pollen grains at some foot-levels where sediments were composed principally of marl. Frequent reference was made to Erdtman (2) as an aid to interpretation of unknown pollens.

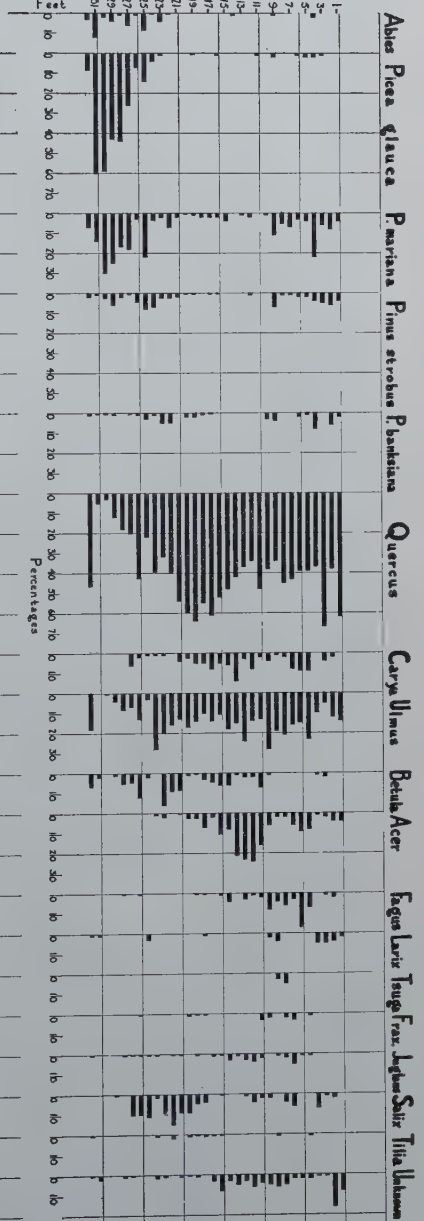
## RESULTS

### LEROY BOG

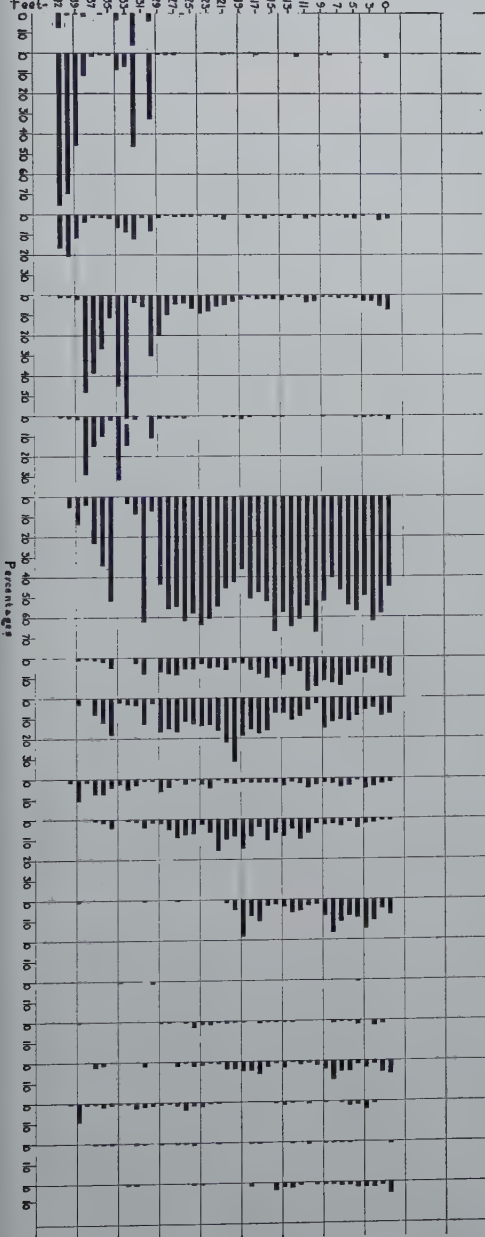
Figure 1 presents the percentage relationship of the genera. It may, however, be desirable to make specific mention of some of the more significant features of vegetational behavior as shown by the percentage figures. Successional trends with marked climatic implications that are difficult to explain are presented in the Leroy bog profile. Chief among these is the initial oak period superceded by a definite *Picea-Abies* period, which in turn is replaced again by *Quercus* twice after an interval represented by 8 foot-levels. From the 24-foot level to the surface, the oak-controlled forest is reflected by high pollen percentages. The persistence of *Picea* to the surface layer is somewhat striking and suggests successful relic participation in a changing association.

*Pinus* is never of great importance in Leroy bog, the greatest percentage representation of the combined species being 12%. *Al-*

# LEROY BOG



# SHOE LAKE



though the percentage increase is slight, pine shows greater abundance in top levels. This leaves the profile without a *Pinus*-dominated period. *Ulmus* is the only other genus with representation in every foot-level. While it exceeds 10% in many instances, it shows two decided peaks at 24- and 10-foot levels.

*Betula*, *Fagus*, *Acer*, and *Carya* appear toward the middle of the profile, they are never of great numerical importance, and decline toward the topmost levels. *Tsuga* and *Larix* are very scattered and represented by very small percentages. For *Tsuga* this expresses a typical Indiana condition.

*Fraxinus*, *Juglans*, *Salix*, and *Tilia* are represented by small percentages which are concentrated primarily at mid-profile levels. With the advent of these broadleaved species, a more complex type of forest is indicated. The increase in percentages of oak and the decline of such genera as *Acer*, *Fagus*, and *Juglans* indicates increasing dryness.

#### SHOE LAKE

The initial forest consisted chiefly of *Picea* and *Abies* which have the extremely high representation of 98.5% in the bottom level. At the 32-foot level *Picea* returns but is sparsely represented above the 30-foot level. *Abies* is absent from the 25-foot level to the top.

The *Pinus* period begins at the 38-foot level and continues through the 30-foot level. It alternates in dominance with *Quercus* and *Picea*. This pine period shows all the characteristics of a transition stage: the point where broad-leaved genera begin to encroach on the coniferous species. *Quercus* is well represented in the 37-, 36-, 35-, and 31-foot levels. It assumes the dominance of the profile at the 29-foot level and retains it to the top with a maximum of 67.5% at the 10-foot level.

*Carya* and *Ulmus* are both fairly prominent in the upper two-thirds of the profile but both diminish slightly toward the top. *Fagus* and *Acer* are both persistent in the top half of the profile and *Acer* continues down into the bottom half with diminishing proportions. *Acer* reaches a maximum of 15.5% at the 22-foot level. *Fagus* reaches its maximum of 18% at the 19-foot level.

*Tsuga* is represented only in three foot-levels, which is very typical for Indiana; while *Fraxinus*, *Juglans*, *Salix*, and *Tilia* apparently played only minor roles in the crown cover.

## DISCUSSION

If the successions shown in a pollen profile lack fluctuations and proceed from an initial spruce-fir forest to one controlled by broad-leaved genera, the interpretations are comparatively clear. This is, however, not the case in the present analysis. Both Leroy bog and Shoe Lake present successions which are difficult to interpret. In studies of this type, one soon realizes that many other factors, not directly concerned with the profile as such, may obscure the real meaning of the pollen records. There is the problem of locating the deepest place in the basin which alone may contain the complete depositional record, as Potzger (9, 10) has shown for a number of bogs in Michigan and Wisconsin.

The most difficult problem in the present study is to account for the initial *Quercus* peak in the Leroy bog (32-foot level), which one is almost certainly justified in declaring impossible if no truncation has entered into the work. If we eliminate this difficulty presented by the *Quercus* dominance in the lowest foot-levels, the successions as shown by the remaining portions of the two profiles are identical or the differences can at least be satisfactorily explained.

If we superimposed the 31-foot level of Leroy bog upon the 32-foot level of Shoe Lake, successions to higher levels are more nearly similar. It is true that in Shoe Lake profile we have oak and pine peaks and troughs which are absent in the Leroy bog. Guennel (5) also failed to find a pine period in the Merrillville bog. More extensive pollen studies in northern Indiana may show that lack of a pine period is a characteristic feature of the forest history in the section of Indiana bordering on the prairie climax.

It is conceivable that these fluctuations in vegetations indicate fluctuations in glacial advances and retreats. Perhaps the glacier receded sufficiently to permit replacement of the pines by the oaks and elms, and subsequent glacial advance again favored the pine. In Leroy bog, likewise, an unstable climate is indicated, but here it involves spruce, pine, and oak. The spectra of Tippecanoe Lake (Potzger and Wilson, 11), Jeff bog (Keller, 6), Lake Cicott (Smith, 12), and Reed bog (Griffin, 4) show some of these fluctuations, especially between *Quercus* and the conifers. In each of the cases cited, *Quercus* has made a prominent entrance before the pine period is evident.

Voss (15) analyzed seven bogs within the Valparaiso Moraine in northeastern Illinois (Lake County). In each of these, pine shows similar fluctuations to those of Leroy Bog, and in most cases the top levels also show fair percentages of pine pollen, indicating relic persistence. Oak makes its entrance in what may be considered a normal manner in all seven bogs, and after assuming dominance, never relinquishes it again. The fact that oak percentages are never high at the bottoms of these bogs (as they are at Leroy) may be further evidence favoring the assumption that the profile is truncated.

As stated before, there is need for further pollen studies in northern Indiana, especially in the northwestern corner (Lake and Porter Counties) and in the Valparaiso Moraine in general, in order to get an understanding of climatically controlled forest behaviors. Guennel (5) was able to show the development of the relic pine consociation at the Merrillville Bog which man of today terminated a few years ago. Similar relic colonies are also indicated in the upper levels of Leroy and Shoe Lake bogs. Fire might have eliminated them just previous to the advent of civilized man. In fact, in Lake County even today may be found scattered colonies of *Pinus banksiana*.

The rapid succession from the spruce-fir period (Shoe Lake, 32-foot level) to the oak-elm stage is important in that it is an indicator of a change from a cold, moist climate to a warm, dry climate within a comparatively short space of time. The rapidity with which these broadleaved trees replaced the conifers is strikingly evident at Shoe Lake (26-foot level). Here in the course of one foot-level there is almost a complete change in forest cover from conifers to broad-leaved genera and as suddenly again in the next foot-level conifers replace broad-leaved genera. At Leroy (26-foot level) the replacement is more gradual.

During the long period following the struggle between the conifers and the oaks, first one and then the other dominating, the association complex was by no means static. True, oak was apparently of greatest abundance, but one is impressed with the "troughs" which are due to increase of abundance of pollens contributed by *Ulmus*, *Acer*, *Fagus*—all genera which suggest improved soil moisture conditions. If one were to point to one factor as being different in the closing foot-levels of Leroy bog from Shoe Lake, it is the decline of *Acer*, *Fagus* and *Juglans* with a compensating increase in oak. Leroy bog

is close to the prairie border and it may mean less favorable rainfall after a period when the fourth foot-level was being deposited.

Undoubtedly the oak pollens are representative of several different species, especially at higher levels. It is possible that the oak pollen found in the lower levels was contributed by *Quercus borealis* var. *maxima*. So far, however, no morphological difference has been discovered by which the several *Quercus* species can be separated.

## SUMMARY

1. This paper presents pollen studies from Leroy bog and Shoe Lake, located in Lake and Kosciusko Counties respectively, in the northern part of Indiana.

2. The purpose of the study was to compare progress of past vegetation in the northwestern corner of the state with that in the north-central section.

3. Both the bog and the lake present spectra that show several fluctuations in forest types in their lower levels, and truncation of the Leroy bog profile is suspected because *Quercus* here precedes the *Picea* period.

4. *Quercus* makes unusually early entrances and re-entrances, alternating in dominance with the coniferous species. These fluctuations are best explained as the result of advances and retreats of glaciers and their effects on climate.

5. Major forest succession shown in Leroy bog is: *Quercus-Ulmus* to *Picea-Abies*, to *Picea-Quercus*, to *Quercus-Ulmus*, to *Picea-Pinus-Quercus*, to *Quercus-Ulmus*.

6. The Shoe Lake spectrum indicates that succession of forests was: *Picea* to *Pinus*, to *Pinus-Quercus*, to *Quercus-Ulmus*, to *Pinus*, to *Picea-Abies*, to *Quercus-Ulmus*, to *Picea-Pinus*, to *Pinus-Quercus-Ulmus*, to *Quercus-Ulmus-Acer-Fagus*, to *Quercus-Ulmus-Carya*, to *Quercus-mixed hardwoods*.

7. Climatic changes at Leroy Bog were apparently comparatively rapid from cold-moist, to warm-dry, and then more gradually to warm-moist climate.

8. The climatic changes suggested by the Shoe Lake profile are: cold-moist, to cool-dry, to warm-dry, to cold-moist, to cool-dry, to warm-dry, to warm-moist.

## ACKNOWLEDGMENTS

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# THE EFFECT OF LARGE AMOUNTS OF CERTAIN VITAMINS OF THE B GROUP ON THE GROWTH RATE AND MORPHOLOGY OF CERTAIN BACTERIA<sup>1</sup>

By ALICE JEANNE GILLUM

From the general literature on the subject of growth stimulants, it appears that large amounts of any growth stimulant will eventually cause a retardation of growth. The purpose of this study was to see what effects high concentrations of some of the vitamins of the B group have on the growth rate and morphology of a few of the common types of bacteria.

The few available papers dealing with vitamins of the B group are concerned with large amounts of nicotinic acid or nicotinamide. Kosar and Kasai (1) report marked retardation of growth when using 3,000, 5,000, and 10,000 gamma/ml of nicotinic acid and nicotinamide. Dorfman et al. (2) reported retardation of dysentery bacilli by concentrations of 3,000, 5,000, and 10,000 gamma/ml of nicotinic acid.

Other papers reporting similar retardations of growth with use of large amounts of nicotinic acid or nicotinamide are those of Koser and Baird (3) and Moller and Birkofer (4). Smaller amounts were found by Rosenfeld and Greene (5) to inhibit growth of *Leptospira*.

## METHODS AND MATERIALS

Stock cultures of all organisms used were grown on Bacto-Nutrient Agar. This medium was also used in the poured plates for the plate counts. Media were adjusted to pH 7.2. A synthetic basal medium was used for the growth of the organisms during the experiments. Five cc. amounts of this medium were tubed and sterilized, and the vitamin solutions were added aseptically when desired. For certain organisms, additional nutrients were necessary to maintain growth. *Proteus vulgaris* required cystine, glutamic acid, and nicotinic acid; *Bacillus subtilis* required cystine and glutamic acid.

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<sup>1</sup> A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

The preparation of the basal medium and additional nutrients is as follows:

Basal Medium (Koser and Kasai).

|                                                        |             |
|--------------------------------------------------------|-------------|
| (NH <sub>4</sub> ) <sub>2</sub> HPO <sub>4</sub> ..... | 2.0 grams   |
| KH <sub>2</sub> PO <sub>4</sub> .....                  | 1.5 grams   |
| NaCl .....                                             | 5.0 grams   |
| MgSO <sub>4</sub> .....                                | 0.1 gram    |
| Glucose .....                                          | 5.0 grams   |
| Distilled water .....                                  | 1,000.0 ml. |

pH 6.8 to 6.9 after autoclaving; must be readjusted after adding large amounts of nicotinic acid.

The following are added for *Proteus vulgaris* and *Bacillus subtilis* cultures:

|                     |             |
|---------------------|-------------|
| Cystine .....       | 0.024 mg/ml |
| Glutamic acid ..... | 1.0 mg/ml   |

For *Proteus vulgaris* cultures:

|                      |            |
|----------------------|------------|
| Nicotinic acid ..... | 1 gamma/ml |
|----------------------|------------|

Vitamins

The following vitamins were supplied, in pure form, by the Eli Lilly Company of Indianapolis, Indiana:

Riboflavin  
Nicotinamide  
Nicotinic acid  
Pyridoxine hydrochloride  
Thiamin hydrochloride

Sterilization of Vitamins

Maximum temperatures for heating of vitamins:

|                                |                 |
|--------------------------------|-----------------|
| Riboflavin .....               | 527° F.         |
| Nicotinamide .....             | 264.2-267.8° F. |
| Pyridoxine hydrochloride ..... | 320° F.         |
| Thiamin hydrochloride .....    | 230° F.         |
| Nicotinic acid .....           | 256° F.         |
| Autoclave at 15 lbs. ....      | 248° F.         |
| Autoclave at 0 lbs. ....       | 212° F.         |

The results of comparative tests showed no real difference in effect whether the vitamins were filtered or autoclaved (including intermittent sterilization). The vitamins were sterilized in dry form in the autoclave at correct temperature and pressure. Distilled water was boiled and autoclaved at 15 lbs. pressure for 20 minutes. The final pH of the distilled water was pH 7.0. Each vitamin was then dissolved in the previously prepared distilled water to give a specific concentration per ml. The correct amount of the vitamin-water solution was added to the tubed basal medium to give the concentrations desired.

Comparative tests showed the addition of largest amount of distilled water used in making proper concentration of vitamin had no effect on growth rate or morphology.

### PROCEDURE

The procedure followed in all experiments is as follows:

1. A 24-hour basal medium culture of the organism was obtained from a pure culture agar slant. All organisms used were Butler University stock cultures.
2. One loopful of this 24-hour basal medium culture was inoculated to each tube of basal medium.
3. The proper concentration of the vitamin was added to each tube.
4. Incubation at 37° C. (for all except *Bacillus subtilis*, which was incubated at 30° C.) for 16, 24, 48, and 72 hours.
5. Agar plates were poured for 16, 24, 48, and 72 hour counts. Dilution method was necessary in the case of high counts.
6. Slides were made at 16, 24, 48, and 72 hour intervals. Staining time was 1½ minutes.
7. Agar plates read by means of a Quebec "Dark Field" counter after 24 and 48 hours of incubation at 37° C. (30° C. for *Bacillus subtilis*).
8. The actual count was recorded and descriptions of the slides made in a record book.

### EXPLANATION OF THE NUMBERS USED IN THE TABLES

The plate count method was used to estimate the count per ml of the basal medium.

The desired end was to obtain an estimate of the trend of growth rather than an actual recording of figures. For this reason, a conversion scale of from 0 to 100 was set up with each step interval equal to 40,000,000 cells, i.e., 0 means from 1 to 40,000,000 cells; 1 means from 40,000,000 to 80,000,000 cells; 2 means 80,000,000 to 120,000,000; etc. Thus, the higher the conversion scale figure, the higher the actual count. Growth rate was recorded on the charts in numbers of from 0 to 100 except where no growth occurred (recorded as NG). In this manner, all major changes in growth rates were shown without the confusion of large figures.

## RESULTS

The general trend found with all vitamins used is that of increasing retardation of growth rate with an increase of vitamin concentration from the 1,000 gamma/ml level to the 10,000 gamma/ml level. There is a considerable tolerance to high concentrations of vitamins. A concentration of 1,000 gamma/ml showed a relatively low degree of effect on growth rate or morphology, while a concentration of 10,000 gamma/ml showed a maximum inhibition of growth and changes in morphology. The cells became swollen, granular, or beaded in appearance, taking the stain very faintly.

Total inhibition of growth occurred in the following cases: nicotinamide used with *P. vulgaris* and *Ps. aeruginosa* (table 5)<sup>1</sup> at the 10,000 gamma/ml level; nicotinic acid (table 6) used with *P. vulgaris* at the 10,000 gamma/ml level; pyridoxine hydrochloride (table 7) used with *P. vulgaris* at the 5,000 and 10,000 gamma/ml level in the 72-hour growth phase and with *Ps. aeruginosa* at the 3,000, 5,000 and 10,000 gamma/ml level; and thiamin hydrochloride (table 9) used with *Ps. aeruginosa* at the 10,000 gamma/ml level.

Cultures which have a conversion scale reading of 0 (definite inhibition but not total inhibition) are more numerous than those showing no growth. The 0 figure is found in the following cases: nicotinamide (table 5): with *P. vulgaris* at the 1,000, 3,000, and 5,000 gamma/ml level in the 16-hour phase of growth and also for the 5,000 gamma/ml in the 24-hour phase of growth; nicotinic acid (table 6): with *P. vulgaris* at the 3,000 and 5,000 gamma/ml in the 16-hour

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<sup>1</sup> Table numbers are those of the original thesis and are not reproduced in the present paper. They are available on loan from the Butler University library.

phase and also for the 5,000 gamma/ml in the 24-hour phase; pyridoxine hydrochloride (table 7) : with *B. subtilis* at the 1,000 gamma/ml in the 16-hour phase and for the 3,000, 5,000, and 10,000 gamma/ml in all phases used, and with *P. vulgaris* at the 1,000 gamma/ml level in the 16-hour phase, at the 3,000 gamma/ml level in the 16- and 24-hour phases, and at the 5,000 and 10,000 gamma/ml level in the 16-, 24-, and 48-hour phases; riboflavin (table 8) : with *P. vulgaris* at the 1,000, 3,000, and 5,000, and 10,000 gamma/ml level in the 72-hour phase and also for the 10,000 gamma/ml level in the 16-hour phase; and finally, thiamin hydrochloride (table 9) : with *B. subtilis* at the 3,000 and 5,000 gamma/ml level in the 16- and 24-hour phases and at the 10,000 gamma/ml level in all phases used, with *P. vulgaris* at the 3,000 gamma/ml level in the 16- and 24-hour phases and at 5,000 and 10,000 gamma/ml levels in all phases, and with *Ps. aeruginosa* at the 5,000 gamma/ml level in the 16-hour phase.

In many cases the initial inhibition at a certain concentration of vitamin will be almost overcome by the time the 72-hour phase is reached. Reference may be made to the following cases: nicotinamide with *P. vulgaris* and *Ps. aeruginosa* (table 5); nicotinic acid with *P. vulgaris* (table 6); pyridoxine hydrochloride with *B. subtilis* and *P. vulgaris* (table 7); riboflavin with *Ps. aeruginosa* (table 8); and thiamin hydrochloride with *B. subtilis*, *E. coli*, and *Ps. aeruginosa* (table 9).

In certain cases the growth at a later growth phase will be lower than at the early growth phases. For example, riboflavin with *B. subtilis* and *P. vulgaris*, (table 8). Riboflavin is very difficult to keep in solution in the amounts used and this may have some bearing on the results.

All organisms used in this experiment need no preformed vitamins (according to latest available data) except *P. vulgaris*, which must have nicotinic acid for growth. In spite of this, some organisms showed increased growth at higher concentrations of the vitamins. For example, nicotinamide with *B. subtilis* at the 10,000 gamma/ml level in 72 hours (table 5); nicotinic acid with *Ps. aeruginosa* at 1,000 gamma/ml level in 24 hours (table 6); riboflavin with *B. subtilis* at the 1,000 gamma/ml level in all growth phases and at the 3,000 gamma/ml level in the 16-, 24-, and 48-hour phases, with *E. coli* at 1,000, 3,000, and 5,000 gamma/ml in the 48-hour phase, with *Ps.*

*aeruginosa* at the 1,000, 3,000 and 5,000 gamma/ml levels in the 16-hour phase (table 8); and thiamin hydrochloride with *B. subtilis* at the 1,000 gamma/ml level in the 16- and 24-hour phases, with *P. vulgaris* at the 1,000 gamma/ml level in all growth phases (table 9).

In a few cases the growth rate went up for several growth phases and later came down again as in the case of riboflavin with *B. subtilis* and *P. vulgaris* in table 8. *B. subtilis* (table 1) appeared to be most sensitive to pyridoxine hydrochloride and thiamin hydrochloride. This organism seemed to be least sensitive to nicotinic acid and nicotinamide. Riboflavin was intermediate in effect.

*E. coli* (table 2) was most sensitive to nicotinamide and pyridoxine hydrochloride. Riboflavin affected this organism the least, while thiamin hydrochloride and nicotinic acid had a somewhat intermediate effect. *P. vulgaris* (table 3) was most sensitive to nicotinamide and nicotinic acid. Thiamin hydrochloride and pyridoxine hydrochloride caused a considerable effect, also. Riboflavin caused the least effect. *Ps. aeruginosa* (table 4) was most sensitive to pyridoxine hydrochloride with nicotinamide and thiamin hydrochloride causing a considerable effect. Riboflavin was the intermediate in effect, and nicotinic acid caused the least effect.

In order of decreasing inhibition, the vitamins affected the organisms in the following manner: (table 5) nicotinamide: *Ps. aeruginosa*, *P. vulgaris*, *E. coli*, and *B. subtilis*; (table 6) nicotinic acid: *P. vulgaris*, *E. coli*, *Ps. aeruginosa*, and *B. subtilis*; (table 7) pyridoxine hydrochloride: *Ps. aeruginosa*, *P. vulgaris*, *B. subtilis*, and *E. coli*; (table 8) riboflavin: *P. vulgaris*, *B. subtilis*, *Ps. aeruginosa*, and *E. coli*; and table 9) thiamin hydrochloride: *Ps. aeruginosa*, *B. subtilis*, *P. vulgaris*, and *E. coli*.

These foregoing comparisons of relative effect were made on a rough basis, taking into account the amount of growth at the 0 level of concentration as compared with the 10,000 gamma/ml concentration. Taking a broad view, *Ps. aeruginosa* and *P. vulgaris* seemed to be more sensitive to the vitamins used in this experiment than did *E. coli* and *B. subtilis*. Pyridoxine hydrochloride and thiamin hydrochloride seemed to cause more inhibition, in general, than the other vitamins used.

As reported by Koser and Kasai (1), *P. vulgaris* needs nicotinic acid for growth. Initial experimentation, using the basal medium

plus cystine and glutamic acid in the required amounts (see Methods and Materials) when attempting to culture *P. vulgaris*, failed. Addition of 1 gamma/ml of nicotinic acid to the basal medium mentioned above supported growth quite well. The other organisms used grew well in the basal medium without the addition of preformed vitamins.

In order to check the effect of large concentrations of vitamins upon the morphology of the cells, slides were made from all concentrations at each growth phase. On examination of the slides, it was found that the cultures which were inhibited in their growth by the excessive amounts of vitamin showed, on staining with crystal violet, swelling and irregular staining ("beaded" staining, faint staining and the like). This irregularity appeared mostly in the 10,000, somewhat in the 5,000, and rarely in the 3,000 gamma/ml concentration. The 1,000 gamma/ml concentration appeared to show none of the irregularities of staining or shape.

## DISCUSSION

Considering the minute amounts of the vitamins which are needed for optimal growth, it is rather surprising to find such a tolerance to high concentrations. 1,000 gamma/ml has really little effect on growth rate or morphology. Concentrations of 3,000, 5,000, and 10,000 gamma/ml must be reached before growth is retarded to any degree. A concentration of 10,000 gamma/ml seems to cause the most marked inhibition, many times causing complete inhibition of growth.

It will be noted that any initial difference in growth rate between the 0 and 1,000 gamma/ml concentrations tends to be overcome in later growth phases. This is also found in some of the 3,000 gamma/ml concentrations and less often with the 5,000 gamma/ml concentrations. In the 10,000 gamma/ml concentration the initial difference in growth rate is rarely overcome.

In the case of riboflavin with *B. subtilis* and of thiamin hydrochloride with *P. vulgaris*, the 1,000 gamma/ml concentration showed more growth than the 0 concentration even through the 72-hour growth phase. In several other cases, the initial growth rate seemed to be greater with the 1,000 gamma/ml concentration than with the 0 concentration, but this difference was overcome by the 72-hour growth phase. In the 10,000 gamma/ml concentration of nicotina-

mide with *B. subtilis* the 72-hour growth rate is greater than in the 0 concentration.

It should be remembered that the environmental conditions of this experiment are rather unbalanced. The cells are supplied large doses of one vitamin while others must be synthesized. Koser and Kasai (1) noted that, in the case of large amounts of nicotinic acid and nicotinamide with casein hydrolyzate, the inhibition was less marked. The same authors also found that yeast extract would nullify the effects of large amounts of nicotinic acid and nicotinamide. This could very well be the case with the other vitamins used in this experiment as it is well known that, when the environmental conditions are less satisfactory, multiplication is difficult and slow, and that changes in the form of bacteria may take place (swelling, faint staining, and granulation).

Hypothetical explanations of the inhibitory effects found in these experiments must surely rest on cellular physiology. It has been suggested in the general literature on cell physiology that alteration in the supply of growth factors will generally have decided repercussions in regard to cell metabolism. Cellular metabolism, depending as it does on a series of enzyme systems, is of necessity affected by factors which affect enzymes. Also, enzymes, being protein complexes, are chemically and physically unstable and sensitive to those factors to which protein complexes are sensitive, such as excessive concentration of any component of the substrate. Stated in another way, we might say that the actual effectiveness of the inhibitor corresponds to its ability to interfere with a chain of synthetic reactions in the cell. So we might conceivably imagine an essential metabolite which stimulates growth at certain levels for certain organisms, becoming, in a sense, an "anti-metabolite" when it reaches higher levels of concentration. "Anti-metabolite" is used here not in the strict chemical sense of a structural analogue but in the broader sense of any substance acting against normal metabolic processes. Viewed in this light, it does not seem so surprising that a growth stimulant, such as a vitamin, when used in large concentrations, should become a growth inhibitor. In fact, it is surprising to find a tolerance to such high concentrations of vitamin. For instance, 0.1 gamma/ml of nicotinamide is said to be sufficient for optimal growth of *P. vulgaris* (Koser and Kasai (1)) while complete inhibition of growth in this experiment did not take place until 10,000 gamma/ml was reached.

All organisms used were known to grow in the basal medium without the addition of preformed vitamins, except *P. vulgaris* which needs nicotinic acid to support growth. In spite of this fact, some of the organisms did show apparent growth stimulation at higher concentrations of vitamins. The probable explanation of this behavior is the fact that these are undoubtedly different strains of the organisms than those for which the original nutritional requirements were worked out. Koser and Kasai (1) report that different strains of *P. vulgaris* proved to have different sensitivity to large amounts of nicotinic acid and nicotinamide. The fact that in most cases no vitamin was used in the first series and 1,000 gamma/ml of vitamin was used as the first concentration would tend to mask the actual concentration at which growth was stimulated. In the cases, where there was apparent growth stimulation at higher than 1,000 gamma/ml level and at sporadic time intervals, some other factor may be responsible for the increased growth shown. Of course, in using the plate count method, one must always take into account the inherent error of the method when sporadic differences of growth occur, even when these are average plate counts. In other words, even using a conversion scale which tends to minimize such inherent error and even when using an average of several experiments, the factor of inherent error in the plate count and in the procedure in general still remains. However, in spite of these unavoidable errors, the results are reliable enough to give us a general trend of growth rate.

It is of importance to note what other workers have found in the few available reports in comparison to the results obtained in this paper. All of the reports deal with nicotinic acid and nicotinamide. For *P. vulgaris*, Moller and Birkofer (4) found that nicotinic acid caused marked reduction of growth or complete inhibition at 0.2 to 0.26 molar (about 30,000 gamma/ml level) concentrations and nicotinamids at 0.056 to 0.066 molar (about 6,000 gamma/ml) concentrations. Koser and Kasai (1) found that nicotinic acid caused marked inhibition at the 10,000 gamma/ml level and the same for nicotinamide. The present results show complete inhibition with nicotinamide at the 10,000 gamma/ml level and the same for the nicotinic acid. Moller and Birkofer (4) used 24- or 48-hour counts in contrast to the 16-, 24- 48-, and 96-hour counts of Koser and Kasai (1) and the 16-, 24-, 48-, and 72-hour counts of the present study.

For *E. coli*, Koser and Kasai (1) find markedly lower growth rate with nicotinic acid at the 10,000 gamma/ml level and very little growth with nicotinamide at the same level up through the 48-hour phase. The present study shows lower growth rate with nicotinic acid at 10,000 gamma/ml level and a markedly lower growth rate with nicotinamide at 10,000 gamma/ml level at all time intervals.

For *B. subtilis*, Koser and Kasai (1) found inhibition for the 16-hour phase at 1,000 gamma/ml and for longer intervals at the 10,000 gamma/ml level. This is for both vitamins. The present study shows *B. subtilis* not to be so sensitive to either vitamin.

The other reports mentioned above reported estimates of comparative growth on the basis of turbidity rather than by actual plate count, hence more detailed comparison of the findings can not be made.

## CONCLUSIONS

1. In low concentrations, certain vitamins of the B group have little effect on *Ps. aeruginosa*, *B. subtilis*, or *E. coli*.
2. Small amounts of added nicotinic acid have a stimulating effect on *P. vulgaris*.
3. Massive doses of certain vitamins of the B group have a retarding effect on growth for the organisms used.
4. There is increasing retardation of growth rate with an increase of vitamin from the 1,000 gamma/ml concentration to the 10,000 gamma/ml concentration when the cultures are grown in a synthetic medium.
5. When there is marked inhibition of growth, the cells become swollen, granular, or beaded and take the stain very faintly.

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# THE FOREST PRIMEVAL OF MARION AND JOHNSON COUNTIES, INDIANA, IN 1819\*

By MARILYN BOWMAN BLEWETT AND J. E. POTZGER

The original forest of eastern North America has been acclaimed the most magnificent deciduous forest the world ever produced, but agriculture encroached very rapidly on this forest so that today in whole counties one cannot find a good representative stand of timber of the primeval forest. This is particularly true for states like Indiana where many counties were blessed with excellent soil, suited to agriculture. Marion and Johnson counties, Indiana are good representatives of such conditions. Fortunately, the original forest has, even though in a meagre way, been recorded both qualitatively and quantitatively by the surveyors working on the original U. S. land survey before the state was divided into county units. For the two counties considered here the record dates back to 1819.

While comparatively few trees enter the tabulation from an extensive area, they may, however, quite accurately portray the percentage relationship of the various tree species which constituted the original forest, as well as the association complex itself. To say the least, they are more reliable and diagnostic than mere verbal descriptions of travelers who chanced to pass through the region in early days of the state.

It is very likely that a few representatives of a mass of vegetation taken at widely separated points within a large area give the same picture as does a concentrated tabulation of a small area. We find this to be true in other situations. At the grain elevator each truck load of seeds is not inspected in its entirety, but quality is determined on basis of a small representative sample. In bacteriology the dilution method used to obtain quantitative and qualitative information on a given culture is without argument accepted as reliable basis for such a study. Still another example of the law of averages is found in the pollen analysis procedure. Small cores are taken from a bog and still smaller samples of these are analyzed, and the pollen present

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\* This is contribution 236 from the Botanical Laboratory of Butler University, Indianapolis, Indiana.

is used to show percentage relationships of the genera which constituted the forest composition of long ago. All such analyses are based on the assumption that the fractional part of a mass is like the whole mass. We assume operation of this law in the present situation.

Marion and Johnson counties were chosen for this study because they adjoin and are located in the glaciated central part of the state where physiography and soil are very similar. The flat tillplain has little relief except where a few streams cut into the unconsolidated glacial till.

## METHODS

Land surveyors had the custom of recording the diameter and species name of two trees, called "witness trees," at each section and quarter section corners. At times additional trees were recorded at intermediate points, especially along river courses. This information we copied on special large sheets showing townships by sections and quarter section division. Since the survey was made before county boundaries were determined, the township or fraction of townships included in a given county were indicated, together with proper range and township designation, on specially ruled worksheets. In fact, the worksheets were duplicates of the divisions shown in the county records deposited in the State Auditor's office. Names of trees and their respective diameters were entered on the township work sheets. From these records final tabulations for percentage representation of various species were made as shown in tables I and II.

The records of the original land survey are filed in the State Auditor's office. Data for Marion County were obtained at the County Surveyor's office. We are grateful to the officials at both offices for the cordial welcome we were given and for the ready help that was given our work.

By way of comparison, a detailed forest survey was made of a comparatively little disturbed stand of climax forest on the Fort Harrison Reservation, near Indianapolis. Results of that survey based on twenty 10-meter-square quadrats are shown in table V.

## OBSERVATIONS

The data summarized in tables I and II plainly show that both counties were fine representatives of the climax mixed mesophytic

type where *Fagus* and *Acer saccharum* played the most prominent role. Diameter of stems was mostly below 30-inches DBH. (tables III and IV). The status of reproduction can be inferred from the abundance of stems in the 3-inch to 6-inch size-classes. Genera and species showing highest abundance in these size-classes are *Acer saccharum*, *Fagus grandifolia* and *Fraxinus* sp.?. *Fagus grandifolia* and *Acer saccharum* combined constitute one-half or more of the stems in all but five of the 28 townships, and *Fagus* alone has 50 per cent representation or more in most of them, reaching a maximum of sixty-nine per cent in Johnson County (tables I and II). While the oaks are much less abundant in number of stems, and appear to reproduce more sparingly than either beech or sugar maple, they have more large stems than either of the species just referred to (tables III, IV). *Carya* does not exceed an abundance of ten per cent in any one township. *Quercus alba* is more abundant than any other species of oak but it, too, does not exceed ten per cent in any township (table 1). Combining hickory with oaks as an ecological group, their maximum representation (Marion County) is 19 per cent (T. 14 N., R. 2 E.) but in most townships it does not exceed ten per cent.

*Fraxinus* sp? are consistently represented in every township of both counties. They, too, give the impression that reproduction was high. *Ulmus* is a consistent associate in the forest complex, but this genus is less abundant than *Fraxinus*. This one would expect in a mixed-mesophytic forest cover, where elm is, being a subclimax floodplain dominant, somewhat out of its optimum habitat requirements. The reports listed 34 species and genera for Marion County and 36 for Johnson County.

*Juglans nigra* and *Liriodendron tulipifera* are sparsely represented, but they contributed some of the largest stem-diameters recorded. The following are species (numbers of such stems are given in parentheses) which have representatives 32-inches and over in diameter: *Acer saccharum* 32 (1), 36 (3); *Fagus grandifolia* 34 (1), 36 (16); *Carya* 32 (1); *Quercus alba* 33 (1), 34 (1), 36 (5), 38 (1), 40 (2), 48 (4), 50 (2), 60 (1), 80 (1); *Quercus borealis* var. *maxima* 33 (1), 36 (3), 38 (1), 40 (1), 48 (5); *Quercus* sp.? 36 (1), 40 (3), 48 (5), 60 (1); *Quercus velutina* 35 (1), 36 (2), 50 (1), 80 (1); *Juglans nigra* 33 (1), 36 (1), 48 (5); *Liriodendron tulipifera* 36 (6), 40 (1),

48 (3), 50 (3), 60 (3) ; *Fraxinus* sp.? 36 (2), 38 (2), 40 (4), 48 (1) ; *Ulmus* sp.? 33 (1), 36 (9), 40 (1), 46 (1), 48 (3) ; *Platanus occidentalis* 33 (1), 36 (4), 48 (2), 75 (1), 84 (1).

Of the second layer trees, *Carpinus* and *Ostrya* have the highest representation in number of stems. The quadrat study at Fort Harrison (table V) presents a forest association very similar to that indicated for Marion and Johnson counties as a whole (tables I and II), except that numbers of species recorded are less in the Fort Harrison stand. However, even the number of species is comparable when one considers any one township in comparison with the quadrat study.

## DISCUSSION

In order to understand the significance of a particular forest type, it is necessary to keep in mind that the association did not just happen but is the result of interactions of many factors. Chief among these is, no doubt, climate, but physiography (microclimate) is unquestionably the determiner of heterogeneous pattern in the great broadleaved forest, where so many species are favored by the climate as a whole. While in a study as the one we present here one cannot well determine the part which microclimate played in the selection of species and associations of species, it can very well be inferred from the fluctuation of abundance of oak-hickory, beech-maple, beech-maple-elm-buckeye in a fractional part of the area (tables I and II).

If one would determine crown cover on basis of group of species having highest per cent abundance in a township there appear up to ten different forest-cover types.

As frequently pointed out by Potzger (1, 2), Potzger and Friesner (3), and Potzger, Friesner and Keller (4), the ultimate climax vegetation for Indiana is apparently a mixed mesophytic forest in which beech and sugar maple are the most important species. The forest primeval of both Marion and Johnson counties was so constituted. These two counties are fine representative locations where good soil with adequate drainage made possible development of the climax forest. Results of the survey also encourage the conclusion that small stands of comparatively little disturbed forest quite accurately picture the association complex of the primeval forest.

## SUMMARY

1. The paper presents data on trees listed in the original U. S. land survey records of Marion and Johnson counties, Indiana.
2. The surveyors list 34 genera and species for Marion County and 36 for Johnson County.
3. A twenty 10-meter-square quadrat study of a relatively little disturbed stand on the Fort Harrison Reservation, near Indianapolis, is presented for comparison.
4. Both counties were apparently covered mostly by typical climax mixed mesophytic forest in which beech and sugar maple were the most important representatives.
5. Beech totalled on an average 50 per cent or more of the total number of stems. Sugar maple was a consistent associate but seldom equalled the abundance of beech.
6. *Liriodendron tulipifera* and *Juglans nigra* were consistently sparsely represented in the forest association, but they played a prominent role in the large-size stems.
7. Results of the quadrat study of a single stand on the Fort Harrison Reservation compare very favorably with the results obtained from the survey records. The opinion is expressed that surveys of small stands of little disturbed forest very likely yield quite accurately the association complex and quantitative representation of species in the forest primeval.

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TABLE I

Percentage which a given tree species had of the total number of stems recorded in townships of Marion County, Indiana, in 1819

| Species                      | T 14 N |       |       | T 15 N |       |       | T 16 N |       |       | T 17 N |       |       |
|------------------------------|--------|-------|-------|--------|-------|-------|--------|-------|-------|--------|-------|-------|
|                              | R.2E   | R.3E  | R.4E  | R.5E   | R.2E  | R.3E  | R.4E   | R.5E  | R.2E  | R.3E   | R.4E  | R.5E  |
| <i>Acer saccharum</i>        | 9.73   | 7.31  | 6.62  | 5.49   | 21.87 | 13.02 | 7.56   | 8.53  | 18.39 | 23.55  | 11.66 | 10.90 |
| <i>Fagus</i>                 | 53.09  | 27.43 | 45.18 | 60.43  | 32.03 | 20.16 | 62.60  | 48.17 | 37.35 | 25.61  | 52.08 | 54.54 |
| <i>Carya</i> sp?             | 6.19   | 9.75  | 2.41  | 3.29   | 5.46  | 7.98  | 5.04   | 1.82  | 2.87  | 7.43   | 4.58  | 6.06  |
| <i>Quercus alba</i>          | 10.61  | 9.75  | 5.42  | 1.09   | 8.59  | 3.78  | 4.20   | 6.09  | 6.32  | 1.65   | 4.16  | 1.81  |
| <i>Q. borealis maxima</i>    | x      | x     | 1.80  | x      | .78   | x     | .42    | x     | x     | x      | 1.66  | 2.42  |
| <i>Quercus</i> sp?           | .88    | x     | x     | x      | .78   | 1.26  | .42    | 1.21  | x     | x      | x     | .73   |
| <i>Quercus velutina</i>      | 1.77   | 1.82  | .60   | 2.19   | x     | .42   | x      | x     | .57   | .82    | .41   | x     |
| <i>Juglans</i>               | 2.65   | .61   | 1.20  | 1.09   | 5.46  | 2.94  | .42    | 2.44  | 2.87  | .82    | 1.25  | .60   |
| <i>Liriodendron</i>          | 2.54   | x     | 2.41  | x      | .78   | x     | x      | 2.44  | .57   | .82    | 1.25  | .60   |
| <i>Celtis</i>                | x      | 6.70  | x     | x      | .78   | 8.82  | .42    | 1.22  | 1.45  | 4.95   | .83   | x     |
| <i>Fraxinus</i> quad.        | x      | x     | x     | x      | x     | x     | x      | x     | .57   | .41    | x     | x     |
| <i>Fraxinus</i> sp?          | 4.42   | 9.14  | 19.87 | 15.38  | 4.68  | 7.56  | 10.50  | 15.24 | 7.47  | 7.02   | 8.75  | 12.72 |
| <i>Ulmus</i> sp?             | x      | 6.70  | 7.22  | 6.59   | 5.46  | 6.72  | 2.94   | 3.04  | 5.17  | 5.78   | 6.25  | 6.06  |
| <i>Carpinus</i>              | .88    | 1.83  | 1.20  | x      | 2.34  | .42   | 1.68   | .61   | 1.15  | .82    | 1.66  | x     |
| <i>Ostrya</i>                | 1.77   | 6.09  | 1.80  | x      | .78   | 3.36  | x      | x     | 1.15  | 1.65   | x     | x     |
| <i>Acer negundo</i>          | x      | x     | .60   | x      | x     | 1.26  | x      | x     | .57   | .82    | x     | x     |
| <i>Aesculus</i>              | 1.77   | 9.75  | x     | x      | 3.90  | 16.80 | 1.26   | 1.83  | 6.32  | 10.74  | 2.50  | 1.21  |
| <i>Asimina</i>               | x      | x     | x     | x      | x     | .421  | x      | x     | x     | x      | x     | x     |
| <i>Cercis</i>                | x      | x     | x     | x      | x     | .421  | x      | x     | x     | x      | x     | x     |
| <i>Cornus florida</i>        | .8849  | x     | x     | 2.19   | .78   | x     | .42    | .61   | .57   | 1.24   | .41   | .73   |
| <i>Crataegus</i> sp?         | x      | x     | .60   | x      | x     | x     | x      | .61   | .57   | x      | x     | x     |
| <i>Fraxinus americana</i>    | x      | x     | x     | x      | x     | .42   | .42    | x     | 2.87  | .41    | .83   | 1.21  |
| <i>Gleditsia triacanthos</i> | x      | .61   | x     | x      | .78   | .42   | x      | x     | x     | x      | x     | x     |
| <i>Gymnocladus</i>           | x      | x     | x     | x      | x     | .42   | x      | x     | x     | x      | x     | x     |



Percentage which a given tree species had of the total number of stems recorded in townships of Johnson County, Indiana, in 1819

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TABLE II—(Continued)

Percentage which a given tree species had of the total number of stems recorded in townships of Johnson County, Indiana, in 1819

| Species               | T 11 |      | T 12 |      | T 13 |      | T 14 |      |
|-----------------------|------|------|------|------|------|------|------|------|
|                       | R.3E | R.4E | R.3E | R.4E | R.3E | R.4E | R.3E | R.4E |
| Crataegus sp?         | x    | x    | x    | x    | x    | x    | x    | x    |
| Gymnocladus           | x    | x    | x    | x    | x    | x    | x    | x    |
| Juglans cinerea       | x    | x    | x    | x    | .41  | x    | x    | x    |
| Morus rubra           | x    | x    | x    | x    | .41  | x    | x    | x    |
| Nyssa sylvatica       | .83  | x    | x    | x    | x    | x    | x    | x    |
| Platanus              | .41  | x    | x    | .42  | 1.78 | .85  | 1.00 | x    |
| Populus deltoides     | x    | x    | x    | x    | x    | x    | 1.00 | x    |
| P. grandidentata      | x    | x    | x    | x    | 1.23 | x    | x    | x    |
| Prunus serotina       | x    | x    | .46  | x    | .41  | .42  | 1.00 | x    |
| Robinia pseudo-acacia | x    | .41  | .46  | x    | .59  | x    | 1.00 | 1.01 |
| Salix                 | x    | x    | .46  | x    | x    | x    | x    | x    |
| Tilia                 | x    | 1.65 | 1.39 | x    | .59  | .85  | x    | 2.02 |
| Swamp Ash             | x    | x    | x    | x    | x    | .42  | x    | x    |
| Spanish Oak           | x    | x    | x    | x    | x    | x    | x    | x    |
| White Beech           | x    | .41  | 1.80 | 1.26 | 2.96 | .85  | 2.41 | 1.61 |

Showing number of stems by diameter classes which a given tree had in the 1819 survey records of Marion County, Indiana

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TABLE IV

Showing number of stems by diameter classes which a given tree had in the 1819 survey  
records of Johnson County, Indiana

| Species                      | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10  | 11 | 12  | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20  | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 38 | 40 | 48 | 50 | 60 | 80 | Total<br>Stems |      |   |
|------------------------------|----|----|----|----|----|----|----|-----|----|-----|----|----|----|----|----|----|----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----------------|------|---|
| <i>Acer saccharum</i>        | 5  | 9  | 7  | 30 | 10 | 13 | 8  | 26  | 4  | 19  | 2  | 12 | 6  | 5  | —  | 15 | —  | 9   | 2  | 1  | —  | 4  | —  | 2  | —  | 1  | —  | 2  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —              | 93   |   |
| <i>Fagus</i>                 | 6  | 24 | 38 | 83 | 34 | 59 | 30 | 137 | 19 | 165 | 10 | 86 | 66 | 29 | 4  | 79 | 2  | 112 | 13 | 14 | 1  | 61 | 2  | 9  | 3  | 4  | —  | 56 | —  | —  | —  | —  | —  | —  | 1  | —  | 7  | —  | —  | —  | —              | 1214 |   |
| <i>Carya</i> sp?             | —  | 5  | 6  | 6  | 5  | 6  | —  | 12  | 1  | 13  | 1  | 6  | 4  | 1  | —  | 7  | —  | 15  | 1  | —  | —  | 2  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —              | 95   |   |
| <i>Quercus alba</i>          | —  | 1  | 1  | 2  | 2  | 1  | 1  | 6   | 1  | 5   | —  | 1  | 1  | 2  | —  | 3  | —  | 5   | 2  | —  | —  | 7  | —  | 1  | —  | —  | 8  | —  | —  | —  | —  | —  | —  | —  | 5  | —  | 1  | 3  | 1  | 1  | 62             |      |   |
| <i>Q. borealis</i>           | —  | —  | 1  | —  | 1  | 3  | —  | —   | —  | 2   | —  | —  | —  | —  | —  | —  | —  | 1   | —  | 1  | —  | 2  | —  | 3  | 2  | —  | 2  | —  | —  | —  | —  | —  | —  | 3  | 1  | 1  | 4  | —  | —  | —  | 27             |      |   |
| <i>Q. macrocarpa</i>         | —  | —  | —  | —  | —  | —  | —  | —   | —  | —   | —  | —  | 1  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1              |      |   |
| <i>Quercus</i> sp?           | —  | —  | —  | —  | —  | 1  | —  | 1   | —  | 2   | —  | 1  | 1  | 1  | —  | 3  | —  | 3   | 1  | —  | —  | 1  | —  | 1  | —  | 1  | —  | 8  | —  | —  | —  | —  | —  | 1  | —  | 3  | 3  | 1  | —  | —  | 32             |      |   |
| <i>Q. velutina</i>           | —  | 1  | —  | —  | 1  | —  | —  | —   | —  | —   | —  | 1  | —  | —  | —  | 1  | —  | 1   | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1              | 9    |   |
| <i>Juglans</i> sp?           | —  | 1  | —  | 1  | 1  | 1  | —  | 2   | —  | 3   | —  | 1  | 1  | —  | —  | —  | —  | 5   | —  | —  | —  | 1  | —  | —  | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 22             |      |   |
| <i>Liriodendron</i>          | 1  | 3  | —  | 1  | —  | 1  | —  | —   | —  | 1   | —  | 1  | 2  | —  | —  | 3  | —  | 2   | 1  | —  | —  | 2  | —  | —  | —  | —  | —  | 2  | —  | —  | —  | —  | —  | —  | 2  | —  | 2  | —  | —  | —  | 26             |      |   |
| <i>Celtis</i>                | —  | —  | 1  | 3  | 1  | 1  | 1  | 2   | —  | 10  | —  | 3  | 2  | 1  | —  | 2  | —  | 4   | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 33             |      |   |
| <i>Fraxinus</i> quad.        | —  | 1  | —  | —  | —  | —  | —  | 1   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | 1  | —  | 3  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 7              |      |   |
| <i>Fraxinus</i> sp?          | 10 | 10 | 5  | 19 | 11 | 22 | 8  | 33  | 3  | 39  | 8  | 19 | 4  | 7  | 2  | 23 | —  | 19  | —  | 4  | —  | 8  | —  | 1  | —  | 2  | —  | 13 | —  | —  | —  | —  | —  | —  | 1  | 1  | 2  | —  | —  | —  | 274            |      |   |
| <i>Ulmus</i> sp?             | 3  | 5  | 5  | 13 | 2  | 2  | 1  | 10  | 3  | 11  | 1  | 4  | 2  | —  | 1  | 6  | —  | 4   | —  | 1  | —  | 9  | —  | —  | 1  | —  | —  | 5  | —  | —  | —  | —  | 1  | —  | 4  | —  | 1  | —  | —  | —  | 95             |      |   |
| <i>Carpinus</i>              | 2  | 9  | 4  | 17 | 3  | 4  | 2  | —   | —  | —   | —  | —  | —  | 1  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 42             |      |   |
| <i>Ostrya</i>                | 1  | 1  | 1  | —  | —  | 1  | —  | 2   | —  | 1   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 7              |      |   |
| <i>Acer negundo</i>          | —  | —  | —  | —  | —  | —  | —  | —   | —  | —   | —  | —  | 1  | —  | —  | 1  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2              |      |   |
| <i>Aesculus</i>              | 1  | 1  | 1  | 4  | 3  | 3  | 2  | 6   | —  | 5   | —  | 3  | 1  | —  | —  | 2  | —  | 1   | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 34             |      |   |
| <i>Betula</i>                | —  | —  | —  | —  | —  | —  | —  | 1   | —  | 1   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2              |      |   |
| <i>Cornus florida</i>        | 2  | 6  | 4  | 13 | 1  | —  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 26             |      |   |
| <i>Cercis canadensis</i>     | —  | 1  | —  | —  | —  | —  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1              |      |   |
| <i>Gleditsia triacanthos</i> | —  | 1  | —  | 1  | —  | —  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2              |      |   |
| <i>Crataegus</i> sp?         | —  | —  | —  | —  | —  | 1  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1              |      |   |
| <i>Gymnocladus</i>           | —  | —  | —  | —  | —  | —  | —  | 1   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | 1              |      |   |
| <i>Morus rubra</i>           | —  | —  | —  | —  | —  | —  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —              | 1    |   |
| <i>Nyssa sylvatica</i>       | —  | —  | —  | —  | —  | —  | —  | —   | —  | —   | —  | —  | —  | —  | —  | —  | —  | —   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —              | 3    |   |
| <i>Populus deltoides</i>     | —  | —  | —  | —  | —  | —  | —  | 1   | —  | —   | —  | —  | —  | —  | —  | 1  | —  | 2   | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —              | —    | 1 |

TABLE IV—(Continued)

TABLE V

Showing number of stems by diameter classes present in twenty ten-meter-square quadrats in the upland forest of Fort Harrison Reservation

| Species                    | 1  | 2  | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 23 | 24 | Totals |
|----------------------------|----|----|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|--------|
| <i>Acer saccharum</i>      | 98 | 40 | 4 | 1 | — | — | — | — | 1 | —  | 1  | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | 146    |
| <i>Fagus</i>               | 1  | 2  | — | — | — | — | — | — | 1 | 1  | 1  | —  | 1  | 1  | 2  | 1  | 3  | 1  | 2  | 1  | —  | 18     |
| <i>Carya cordiformis</i>   | 3  | —  | 1 | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 4      |
| <i>C. ovata</i>            | —  | 2  | — | — | — | — | — | — | — | —  | —  | —  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | 3      |
| <i>Quercus alba</i>        | —  | —  | 1 | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1  | —  | 2      |
| <i>Q. borealis maxima</i>  | —  | —  | 1 | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1      |
| <i>Q. muhlenbergii</i>     | 1  | —  | — | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1      |
| <i>Juglans nigra</i>       | —  | —  | — | — | — | — | 1 | — | 1 | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2      |
| <i>Celtis occidentalis</i> | —  | 1  | — | 1 | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2      |
| <i>Fraxinus americana</i>  | —  | 1  | — | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1      |
| <i>Ulmus americana</i>     | 3  | 4  | 7 | 2 | 2 | 2 | 1 | 2 | 1 | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 24     |
| <i>U. fulva</i>            | —  | 2  | 2 | 1 | 2 | 3 | 3 | 3 | 2 | 1  | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 20     |
| <i>U. racemosa</i>         | —  | 3  | 4 | 2 | 1 | — | 1 | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 11     |
| <i>Carpinus</i>            | 2  | 2  | — | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 4      |
| <i>Ostrya</i>              | 2  | 4  | 1 | 1 | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 8      |
| <i>Morus rubra</i>         | —  | —  | — | — | — | — | 1 | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 1      |
| <i>Platanus</i>            | —  | —  | — | 2 | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2      |
| <i>Prunus serotina</i>     | —  | —  | 2 | — | 1 | — | 1 | — | 1 | —  | 1  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 6      |
| <i>Cercis</i>              | —  | —  | — | 1 | — | 1 | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 2      |
| <i>Cornus florida</i>      | 1  | 1  | 1 | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 3      |
| <i>Vitis</i> sp?           | 7  | 3  | 1 | — | — | — | — | — | — | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | —  | 11     |

# THE PHYTOPLANKTON OF TWO ARTIFICIAL LAKES IN HENDRICKS COUNTY, INDIANA<sup>1</sup>

By GROVER W. COOK

The small artificial lake has become an important and increasingly popular project for conservation groups, sporting clubs, municipalities, farmers, and landowners. Its purpose is often defined as being for the propagation of fish, the prevention of soil erosion, the restoration of wildlife, and recreation. To this might be added: water conservation, flood control, and food production by fish-pond farming. The Conservation Department of the State of Iowa reports nearly 2000 artificial lakes having been constructed in that state since World War II. When one considers the many thousands of acres of fertile farm land save from flooding streams, the hours of leisure time spent by the factory or office worker on the banks of these ponds, and the havens provided for the wildlife, the worthiness of these projects can easily be realized.

However, it has been characteristic that nearly every artificial lake has been a good producer of fish and a clean place for the swimmer in its first two or three years of existence and then became a poor fish pond and practically unfit for swimming, due to the algal blooms. It is apparent that age is a factor in the limnological consideration of an artificial lake. For that reason two lakes were investigated, one ten years older than the other, in the attempt to determine the correlation between a young lake and a comparatively old one with respect to the abundance and occurrence of the genera of phytoplankton and the total phytoplankton.

## LOCATION AND CONDITIONS OF INVESTIGATION

This study covers a period of six months (December 13, 1949 to May 24, 1950) in which phytoplankton was collected from two artificial lakes in Hendricks County, Indiana, i.e., Hurst Lake and Conservation Club Lake.

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<sup>1</sup> A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

These two lakes were chosen for the investigation because of their close similarities in many features other than age. Both are approximately seven acres in area, and are fed by numerous small springs which flow through pastureland. The trees and other plant life surrounding the lakes are alike in that beech, maple, sycamore, *Ostrya*, and the wild grasses typical of this region, predominate. Animal life observed were: a flock of domestic ducks, muskrats, squirrels, many species of birds, and wild ducks during the migratory seasons. Weekly temperature readings for three months showed a variation of not more than one degree centigrade between the two lakes. Tests of the pH were identical.

Hurst lake is the older, having been built in 1938, and is a good example of the artificial lake that has been high in fish production for the first few years of existence and then declined to mediocrity. It was built by federal WPA funds for the purpose of preventing soil erosion, flood control, propagation of game fishes, and preservation of wildlife. The lake lies two miles south of Danville, Indiana, on State Road 39. (T. 15 N., R 1 W., S. 22).

The Conservation lake was constructed in 1948 by the Danville Conservation Club for the purpose of providing recreation for club members in the form of fishing and boating, and for the purpose of wildlife propagation and preservation. The lake is located one mile northeast of Danville. (T. 15 N., R. 1 W., S. 3).

As this survey was begun in winter, it was necessary at times to chop away the ice to collect samples. In this event, the water was permitted to become settled before sampling. And wherever large amounts of silt prevented microscopical examination, the samples were discarded. For that reason, during a period of heavy rainfall in January, no samples were enumerated.

The samples for plankton counting were collected weekly between 8:00 A.M. and 10:00 A.M. Collections were made at three stations on each lake. The stations on the Conservation Club lake were numbered C-1, C-2, and C-3, and the stations on Hurst lake were numbered H-1, H-2, and H-3. Stations C-1 and H-1 were located near the main inlets of the lakes, the shallowest part of each lake; C-2 and H-2 were on the main body of the lake where the water was three to four feet deep; and C-3 and H-3 were at the end of the dam on each lake

at a point furthest from the spillway. Each of the six stations was three feet from shore.

One liter of lake water was collected from each station and taken immediately to the laboratory at Butler University for enumeration.

## METHODS AND APPARATUS

The following procedure was used in the investigation: (1) collection of samples; (2) concentration by filtration and preservation of the residuum; (3) microscopical examination of the concentrate; (4) enumeration of the phytoplankton.

The 1000 cc. samples were taken immediately to the laboratory collection and concentrated. The procedure used was the Sedgwick-Rafter method in which the 1000 cc. sample was filtered through Berkshire sand and silk bolting cloth. The sides of the Sedgwick-Rafter filter were washed continuously with distilled water to decrease the error factor due to the adherence of the organisms to the glass. When all the water had run through, the stopper was removed and 10 ml of distilled water was used to wash the residuum into a small glass jar. A 10-ml pipette with rubber tubing attached proved very useful for this because the fine stream of water under pressure made it possible to wash thoroughly out of the filter all remaining particles.

One ml of this concentrated sample was then placed into a Sedgwick-Rafter plankton counting chamber by means of a 1-ml pipette. It was allowed to stand about five minutes before examination, to permit most of the organisms to settle to the floor of the chamber. The counting chamber was then placed on the mechanical stage of the microscope and examined by using a 20X objective and a 12.5X ocular. The ocular was fitted with a Whipple plankton counting ocular micrometer, the outer boundaries of which form a square field and measure exactly one square mm of the counting chamber when the draw tube of the microscope is properly adjusted. Since the depth of the counting chamber is one mm, one cubic mm or .001 ml of the concentrate was examined. By including ten fields along the linear axis of the counting chamber from one end to the other, .01 ml was examined. Thus the total number of organisms in ten fields would be equal to the number in one ml of the original sample collected. In order to determine more carefully the genera observed, and since there

was a predominance of Bacillariophyceae, permanent slides were made of all samples where identification was difficult. These were then examined with the oil immersion lens.

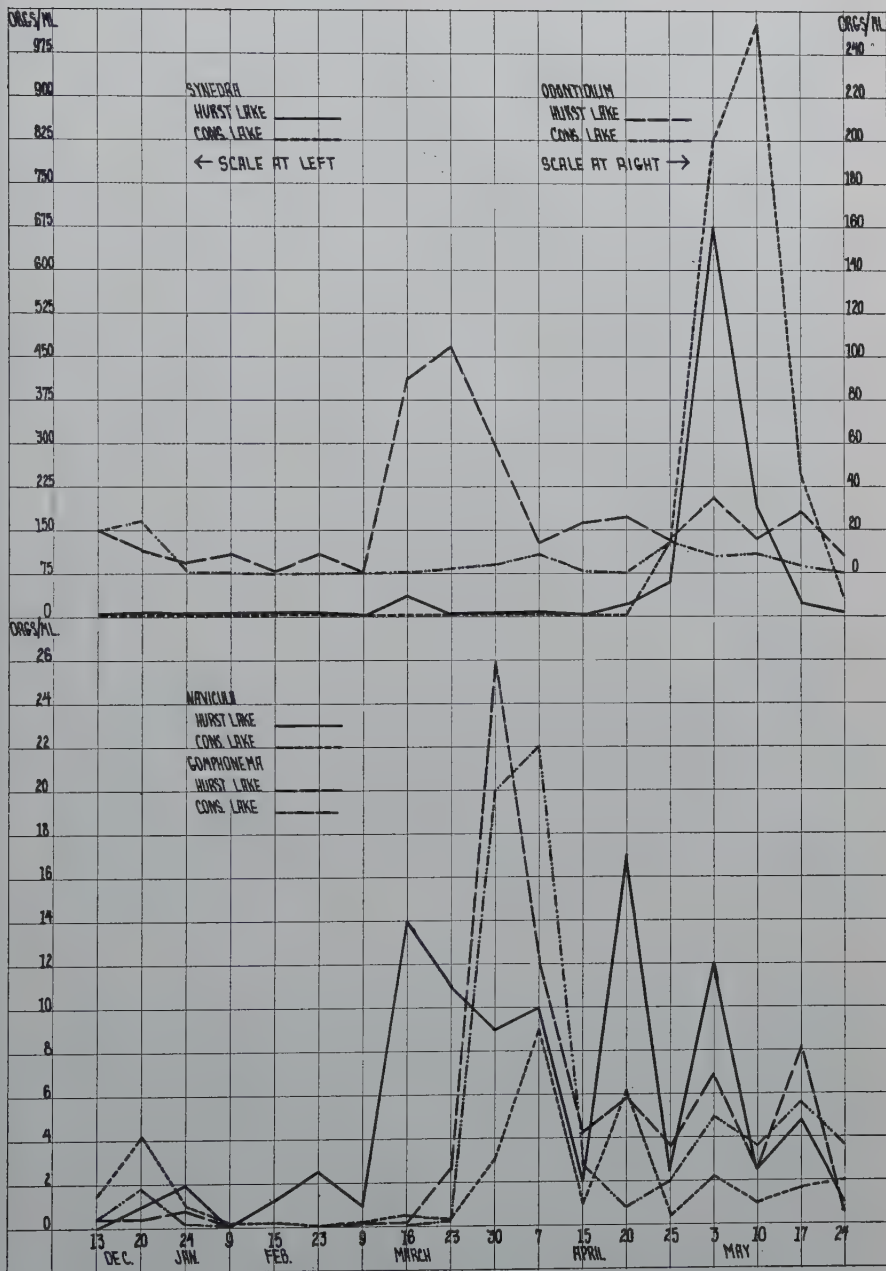
Each unicellular organism was counted as one, and each filamentous form was counted once for each of the smaller squares it touched upon.

## RESULTS

In the 108 samples collected from Hurst lake and Conservation Club lake (hereafter referred to as H lake and C lake, respectively) 37 genera of algae, representing the following classes, were recorded: Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Euglenophyceae, Myxophyceae, and Xanthophyceae.

A wide range in the average total number of organisms was displayed between December 13 and May 24. The lowest average for the three stations on each lake was 1.3 organisms per ml on March 16. This was for samples collected on C lake. The highest average for both lakes was the count for May 24 from H lake when the total was 9035 per ml. H lake had no average below 5.7 per ml, which count was on February 15. C lake had no count higher than 1585, on May 3. H lake was consistently higher in average numbers of organisms per ml until April 25. On that day, H lake averaged 111 per ml and C lake averaged 348.7 per ml. On May 3, C lake was again higher with 1585 per ml against 974 per ml for H lake. The May 10 averages were: C lake, 1404 per ml; H lake, 531 per ml. This increase by C lake was due to the sudden occurrence of large numbers of *Cyclotella* and an increase in the amount of *Synedra*. After May 10, however, there appeared ever-increasing quantities of *Anabaena* in H lake, which averaged 4235 per ml on May 17, and 8941 per ml on May 24. The average number of total organisms per ml for those two dates were 4326 and 9035, respectively. C lake in the meantime dropped in total numbers from 660 per ml on May 17 to 107 per ml on May 24.

A correlation between the older H lake and the younger C lake is evident on the basis of total number of organisms. Except for the three weeks from April 25 through May 10, the older lake at all times was shown to be a better producer of phytoplankton. The older lake is a better producer of Myxophyceae as well. Indeed, a "bloom" of *Aphanizomenon flos-aquae* was observed on H lake by the writer in



late October 1949, and on that same day, no blue-greens could be found in samples collected at C lake.

If it is possible, as Prescott (6) predicts, to arrive at one or more genera as indicators, it might be well to consider the diatoms, especially *Synedra*, *Gomphonema*, *Navicula*, and *Odontidium*.

*Synedra* (fig. 1). The abundance and occurrence of *Synedra* for both lakes is typical of the total number of organisms for both lakes up to May 10. H lake was higher in *Synedra* until April 25, and after that date, C lake was higher. It is noted that *Synedra* reached a peak in early May and declined to a point near the winter averages at the end of the month. Coffing (1) also pointed out *Synedra* as an important organism in her analysis of the White River Canal. Her results show a peak of *Synedra* in March. However, her counts of *Synedra* included *Nitzschia*, which this writer considered separately.

The C lake average for *Synedra* ranged from the winter time lows of near zero per ml to a high of 1025 organisms per ml on May 10. Only four collections failed to contain *Synedra*. The H lake average for *Synedra* ranged from 0 to per ml to 685 per ml. Only one collection was lacking in *Synedra*.

*Navicula* (fig. 2). *Navicula* again characterizes the total for the two lakes, but here the count for C lake was greater, and then only slightly, on two dates, January 24 and May 24. The lines of the graph, for the most part, run nearly parallel, which might indicate the difference that exists between a lake ten years older than another. It must be admitted, however, that the amount of *Navicula* was comparatively small. Thus its use as an indicator might be dependent on the amount of material encountered.

*Gomphonema* (fig. 3). Members of this genus occurred in relatively small numbers, but like *Navicula* and *Synedra*, H lake samples contained larger numbers of organisms than did C lake. Here a peak was reached in late March and early April; the peak for C lake coming one week later than the peak for H lake. *Gomphonema* was present in both lakes represented by many species. This made rapid identification difficult and would probably detract from its value as an indicator.

*Odontidium* (fig. 4). The frequency of appearance of *Odontidium* displayed very well the contrast between the two lakes. In just

one instance was it more abundant in the younger lake. It is peculiar that a comparison of graphs for *Gomphonema* and *Odontidium* are very similar in appearance. Peaks were registered at about the same time. And it is singular that H lake reached a peak for *Odontidium* but that C lake actually never showed a genuine peak. This may or may not be significant. It would be interesting to compare the results of the present investigation with a like study ten years hence. All things being equal, it might be expected that *Odontidium* would be greater in abundance with increased age.

In the above four diatoms lies the only indication, in so far as this investigation shows, that there could be one or more genera or species which might be used as an index of the phytoplankton abundance of an artificial lake. But regardless of whether or not these diatoms might be useful as indicators, it is clearly evident that the older lake is a better producer of phytoplankton than the younger lake.

Some writers hold that the drainage basin is responsible for supplying the lake with plankton. This apparently was not the case with either of these two lakes. January and February were months of exceptionally heavy rainfall. C lake was, at one time, during February, three feet above the normal level of water, and H lake was higher at the same period than it had been in the previous four years. Still, despite this abnormal high water level, which was due mostly to drainage from their respective feed stream drain regions, no increase in total plankton was evident at any time. And a plankton pulse would be expected if one were to believe that the feed streams carried organisms into the lake. Tables I and II, giving detailed results, occur in the original thesis and are available on loan from the Butler University Library.

## SUMMARY

1. A quantitative study of the phytoplankton of the two artificial lakes differing in age by ten years was made from December 13 to May 24.

2. Seven classes of algae were recorded: Bacillariophyceae, Chlorophyceae, Chrysophyceae, Dinophyceae, Euglenophyceae, Myxophyceae, and Xanthophyceae.

3. The Bacillariophyceae were the predominant organisms from December through April. Of the diatoms recorded, four genera oc-

curred in nearly every weekly collection, viz. *Synedra*, *Navicula*, *Gomphonema*, and *Odontidium*.

4. *Anabaena* was the predominant blue-green alga.

5. The only genus of the Chrysophyceae found was *Dinobryon*.

6. *Cyclotella* was abundant in the Conservation Club Lake during April and May.

7. Taking the averages for three stations on each lake, only twice did the younger lake surpass the older one.

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# FOREST AND PRAIRIE IN THREE NORTH-WESTERN INDIANA COUNTIES\*

By FRED W. ROHR AND J. E. POTZGER

The modifying influence of civilized man on natural vegetation is so rapid and so extensive that it becomes a difficult problem after a century or more to picture the original vegetation cover. The task is still more difficult when one attempts to express the vegetation in quantitative terms. Today the taxonomists scour the railway right-of-way for specimens of prairie plants for the prairie itself with its plant sociology has vanished. We will never be able adequately to reconstruct this vegetation complex, and we can only with difficulty draw its former boundary. Even though the surveyors of the original United States land survey, whose records form the basis of this study, made copious notes on prairie areas, it is likely that sedge-meadow type of vegetation was included under their classification of "wet prairie." If the term actually described areas dominated by typical prairie grasses, then Indiana at that time had wet prairie, dry prairie and a transition type of prairie and forest association, park-like in nature, which might be called oak openings.

In the absence of trees to bear witness of corners, the surveyors placed posts. This system outlines treeless areas very definitely, and the ecotone condition, where prairie and forest compete, is shown by reduced abundance of stems listed for a given township and by the frequent use of posts as witness markers. In typical forested counties in Indiana the number of stems recorded is usually three times as great as in Lake, Newton and Jasper counties.

## METHODS

Data were taken from the records of the original United States land survey in Lake, Newton and Jasper counties. The adjoining southernmost four prairie counties will be considered in another paper.

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\* This is publication 238 of the Botanical Laboratory of Butler University. We express our thanks to Mrs. Margaret Esther Potzger for the lettering on figure 1. The senior author expresses his appreciation to Butler University for a Butler Faculty Fellowship which aided in the series of studies dealing with the original vegetation of Indiana.

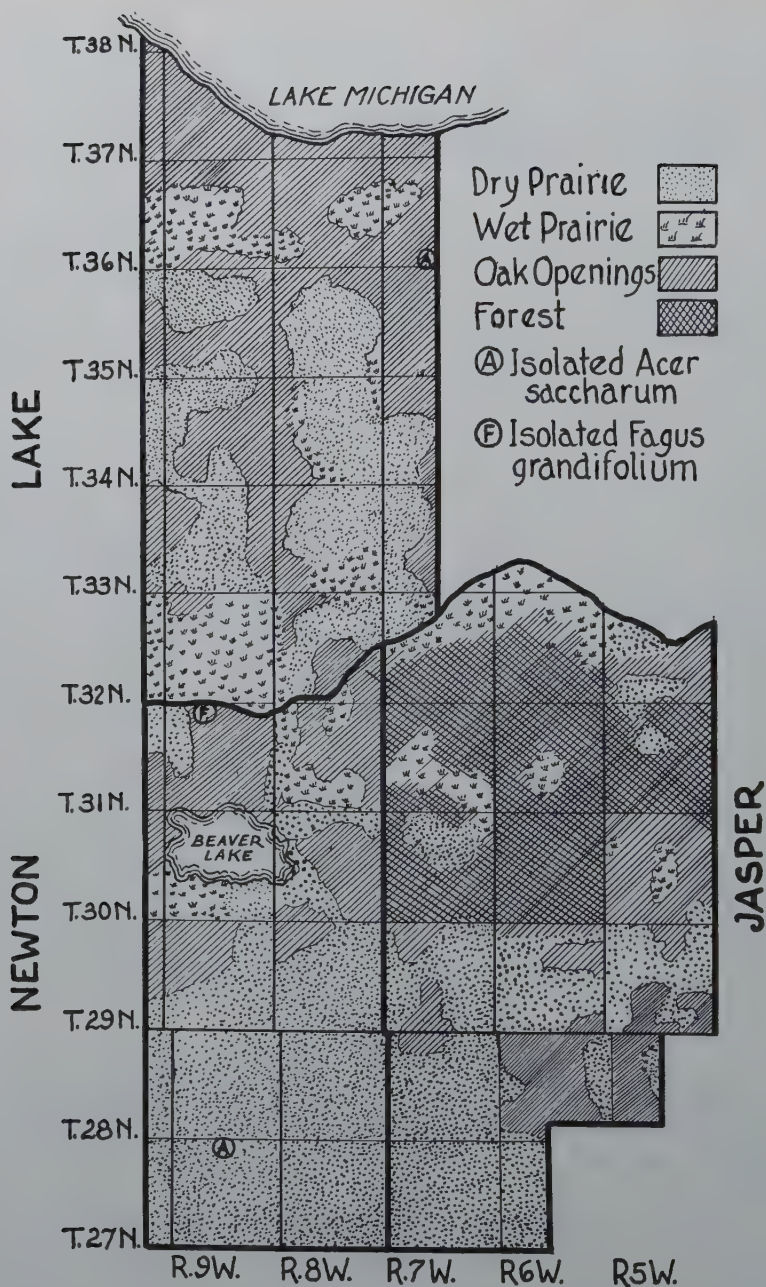


FIGURE 1

Graphic presentation of the four major vegetation types in Lake, Newton and Jasper counties, Indiana.

In locations where the surveyors' notes list only posts, the condition was interpreted as prairie. This assumption was further validated by notes on the region. Forest composition is shown in tables I-III, where total number of stems of the various species and genera are given for township units. The surveyors' Jack oak is included under *Quercus ellipsoidalis*, swamp oak under *Quercus bicolor*, and Spanish oak under *Quercus palustris*.

When the total number of stems recorded in a given county is very small then the method of expressing representation of the various species by percentages gives an erroneous impression of crown control. In fact, there was very likely no real crown control by arboreal species in the three counties. For that reason, in tables I-III, number of stems rather than percentages are given. Figure 1 presents the localities where use of posts suggested typical prairie conditions.

## OBSERVATIONS

The northwestern three counties in Indiana present a number of features which might be interpreted as contact between two major formations, with ecotone conditions intervening. The prairie in Indiana no doubt had scattered trees even in areas of its best expression, and the open forest very likely had prairie grasses as under-story vegetation—for crown cover of the trees must have been very open. This is indicated by the small number of stems recorded and frequent use of posts to mark corners. When comparison is made between these three counties, and densely-wooded townships of central Indiana described by Blewett and Potzger (1) and Potzger and Potzger (3) the prairie influence is strikingly shown by the small number of stems in certain townships of the present study. Real forest cover was found perhaps only in Jasper County (T.30 N., R. 5W. and T.30 N., T.31 N., T. 32 N., R. 6 W and R. 7 W.). These counties also mark the western limits of *Acer saccharum* (Newton County, T. 27 N., R. 9 W., and Lake County, T. 36 N., R. 7 W.) and *Fagus grandifolia* (Newton County, T. 31 N., R. 9 W.). In Lake County we also find the southern limits for western Indiana of Jack pine and arbor vitae. The forest is marked by its abundance of oak. Dominating were *Quercus alba*, *Q. velutina*, *Q. macrocarpa* and "yellow oak." In Jasper County and Newton County *Carya* played a very insignificant role; but in T. 33, 34, 35 N., R. 7, 8 and 9 W. in Lake County, *Carya* was sufficiently abundant to justify the classification of the forest as

of the oak-hickory type. The more mesic genera are wanting in these counties, or appear only sparingly.

Unfortunately there is no definite way to know which characteristics the surveyors used to differentiate between black and yellow oaks. In central Indiana yellow oak was not listed, but black oak was recorded. If black and yellow oaks are, indeed, synonymous then black oak was the most abundant of all oaks in these counties. *Quercus macrocarpa* was abundant in the greater part of Lake County and in some townships of Jasper County. Stems of trees measuring 36 inches DBH. or over were as follows: (Lake County *Quercus alba* 4, *Q. rubra* var. *borealis* 1, *Q. macrocarpa* 6, yellow oak 3, *Q. palustris* 2, *Pinus strobus* 1; (Newton County), *Quercus alba* 8, *Q. rubra* var. *borealis* 1, *Q. macrocarpa* 2, *Q. velutina* 11; (Jasper County) *Quercus alba* 20, *Q. macrocarpa* 11, *Q. velutina* 3, *Q. ellipsoidalis* 1, yellow oak 5, *Platanus occidentalis* 3. This makes a total of 83 stems for the three counties. In general, the diameter of stems was small, most of the trees ranged between 4 and 20 inches DBH. Only 1.6 per cent of the stems ranged from 36 inches DBH. upward. According to the field notes, *Pinus strobus*, *P. banksiana* and *Thuja occidentalis* were limited to a belt about a mile inland from Lake Michigan. While the forest is constituted chiefly of various species of oaks, habitat played a selective role. *Quercus palustris*, *Q. bicolor*, and *Q. macrocarpa* are favored by wet soil, *Q. rubra* var. *borealis* and yellow oak by medium-wet soils, and *Q. velutina* by dry, sandy soil. *Quercus alba* appears to be cosmopolitan, as Potzger (2) found the same species to be in Ripley County.

## DISCUSSION

The vegetation pattern in the three counties is really quite clearly defined and rather simple in structure. A grassland vegetation yields to an ecotone oak opening type of tree-grass vegetation, and this in turn merges into a definite oak or oak-hickory forest association (T. 30N. to T. 32N., R. 6W. and R7.W.). For want of any studies on climatic and edaphic factors, it would be folly to venture an explanation of the causes underlying the variation in vegetation, even within the confines of a single county. However, the sharp demarkation between individual species and between associations is striking evidence that a climatic or edaphic selection operates. Potzger and Keller (4) found that *Fagus* declines progressively from township to

township as one moves from south, east and north into the prairie area. One is impressed, however, that microclimate permits such mesic species as *Fagus grandifolia* and *Acer saccharum* to extend a disjunct range into otherwise inhospitable environment, considerable distance from the great mass of their mesic association (Fig. 1).

These phenomena indicate that the habitat changes progressively as one proceeds into the grass-controlled areas. From a mixed mesophytic forest association the more mesic species, like *Fagus* and *Acer saccharum* drop out first, and the more xeric oaks and hickories maintain the crown control. As one moves into the ecotone trees decrease in number as well as in diameter of stems, indicating increasing difficulty for forest to maintain dominance at all. Finally, of course, forest yields to a grass association. These are the bare facts, and it is perhaps all one should expect of the study. It has its greatest significance in the factual data rather than in its explanatory value. In fact, statistical records from surveyors' notes and tabulations make no claim for explanation. In this study they project only the dramatic behavior of plants, both as individuals and as associations, along boundaries of critical habitat conditions, giving not even a hint whether the control is due to aerial or edaphic factors. They do point to the need of additional detailed habitat and climatic studies which might give some explanation of the striking controls on vegetation which are revealed by the statistical data.

## SUMMARY

1. The paper presents data on the vegetation of three northwestern Indiana prairie counties (Lake, Newton and Jasper) as recorded in the field notes of the surveyors associated with the original United States land survey.

2. Four types of plant associations are present, viz. dry prairie, wet prairie, oak openings, and oak or oak-hickory forests.

3. Only in Lake County is hickory sufficiently abundant to warrant classification of the forest cover as of the oak-hickory type.

4. The most prominent oaks are *Quercus alba*, *Q. velutina*, *Q. macrocarpa* and "yellow oak" (the authors have no criteria to differentiate between the surveyors' "yellow" and "black" oaks).

5. In townships where only, or primarily, posts were used as witness markers prairie conditions are assumed. In the field notes such treeless areas were classified as wet or dry prairie.

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TABLE I

Species or genera of trees, and number of stems of each, recorded in townships of Lake County

| Names of Trees              | Ranges west |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
|-----------------------------|-------------|----|----|----|----|----|----|----|----|----|-------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--|--|--|--|--|--|
|                             | 7           |    |    |    |    |    |    |    |    |    | 8           |    |    |    |    |    |    |    |    | 9  |    |    |    |    |    |    |    |    | 10 |    |    |    |    |  |  |  |  |  |  |
|                             |             |    |    |    |    |    |    |    |    |    | Towns north |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
|                             | 32          | 33 | 34 | 35 | 36 | 37 | 32 | 33 | 34 | 35 | 36          | 37 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 31 | 32 | 33 | 34 | 35 | 36 | 37 |  |  |  |  |  |  |
| Acer rubrum, A. saccharinum | 4           | 2  |    |    |    |    | 4  |    |    |    |             |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| A. saccharum                |             |    |    |    | 1  |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Alnus sp.?                  |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Betula sp.?                 |             |    |    |    |    |    | 1  |    |    |    |             |    | 6  | 5  |    |    |    |    | 2  | 8  |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Carya sp.?                  | 14          | 20 | 32 | 4  |    |    | 12 | 20 | 16 | 1  |             |    | 2  | 15 | 23 | 16 |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Fraxinus sp.?               |             |    |    |    |    |    |    |    |    |    |             |    | 6  |    |    |    |    |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| F. americana                | 19          | 10 |    |    |    |    | 4  | 1  |    |    |             |    |    |    |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| F. nigra                    | 6           |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Juglans nigra               |             |    |    | 1  |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Pinus sp.?                  |             |    |    |    | 2  | 4  |    |    |    | 1  | 13          |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| P. strobus                  |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Yellow pine                 |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Platanus occidentalis       |             |    |    | 1  |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Populus sp.?                | 3           | 2  | 2  |    |    |    | 3  | 4  | 2  | 2  |             |    | 3  |    |    |    |    |    | 7  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Prunus serotina             |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Quercus alba                | 1           | 5  | 7  | 12 | 56 | 7  | 11 | 8  | 31 | 10 | 38          | 3  | 1  | 16 | 21 | 51 | 33 | 34 | 14 | 1  | 4  | 5  |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Q. ellipsoidalis            |             |    |    | 3  |    |    |    |    |    |    | 2           |    | 3  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Q. macrocarpa               | 7           | 31 | 9  | 3  |    |    |    |    |    |    | 23          |    |    |    |    |    |    |    | 1  |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Q. palustris                | 1           |    |    |    |    |    | 14 |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Q. rubra var. borealis      | 1           | 1  | 6  | 3  |    |    | 2  | 2  | 1  | 3  | 3           |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |
| Q. velutina                 |             |    |    | 18 | 6  |    |    |    |    |    |             |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |  |  |  |  |  |  |

TABLE I—(Continued)  
Species or genera of trees, and number of stems of each, recorded in townships of Lake County

| Names of Trees     | 7  |    |    |     |     | 8  |    |    |    |    | Ranges west |    |             |    |    | 9   |     |     |    |    | 10 |    |    |    |    |    |    |    |    |    |    |
|--------------------|----|----|----|-----|-----|----|----|----|----|----|-------------|----|-------------|----|----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|----|
|                    | 32 | 33 | 34 | 35  | 36  | 37 | 32 | 33 | 34 | 35 | 36          | 37 | Towns north |    |    |     |     | 31  | 32 | 33 | 34 | 35 | 36 | 37 | 31 | 32 | 33 | 34 | 35 | 36 | 37 |
| Spanish oak        | 1  | 1  |    | 2   |     |    |    |    |    |    |             |    |             |    |    |     |     |     |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Yellow oak         |    | 10 | 13 | 35  | 31  | 5  | 5  | 5  | 9  | 19 | 104         | 20 | 12          | 14 | 17 | 52  | 84  | 32  | 1  | 4  | 6  | 2  | 4  | 13 | 13 |    |    |    |    |    |    |
| Salix sp.?         | 2  | 2  | 1  |     |     |    | 4  | 3  |    |    |             |    | 3           | 4  | 1  |     |     | 1   |    |    |    |    | 1  |    |    |    |    |    |    |    |    |
| Tilia americana    |    |    |    | 1   |     |    |    |    |    |    |             |    |             |    | 1  |     |     |     |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Thuja occidentalis |    |    |    |     |     |    |    |    |    |    |             |    |             |    |    |     |     | 2   |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Ulmus sp.?         | 1  | 3  |    |     |     |    |    | 1  |    |    |             |    |             |    |    |     |     | 2   |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Total stems        | 28 | 65 | 78 | 119 | 116 | 16 | 48 | 53 | 91 | 98 | 172         | 36 | 14          | 75 | 94 | 140 | 160 | 123 | 93 | 6  | 20 | 23 | 4  | 32 | 19 | 20 |    |    |    |    |    |



TABLE III  
Species or genera of trees, and number of stems of each, recorded in townships in Jasper County

| Names of Trees              | 5           |    |     |     |     |    |     |    |     |     | 6           |    |    |    |    |    |    |    |    |    | 7           |    |    |    |    |    |    |     |    |    |    |
|-----------------------------|-------------|----|-----|-----|-----|----|-----|----|-----|-----|-------------|----|----|----|----|----|----|----|----|----|-------------|----|----|----|----|----|----|-----|----|----|----|
|                             | Ranges west |    |     |     |     |    |     |    |     |     | Ranges west |    |    |    |    |    |    |    |    |    | Ranges west |    |    |    |    |    |    |     |    |    |    |
|                             | 28          | 29 | 30  | 31  | 32  | 27 | 28  | 29 | 30  | 31  | 32          | 27 | 28 | 29 | 30 | 31 | 32 | 27 | 28 | 29 | 30          | 31 | 32 | 27 | 28 | 29 | 30 | 31  | 32 |    |    |
| Acer rubrum, A. saccharinum |             |    |     | 6   | 2   |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 19 | 11 |    |    |    |     |    | 20 |    |
| Betula sp.?                 |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             | 6  | 2  |    |    |    |    |     |    | 2  |    |
| Betula nigra                |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Carya sp.?                  |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Fraxinus sp.?               | 4           | 3  | 3   | 3   |     |    |     | 1  | 5   | 1   |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    | 7  | 4  | 1   |    |    |    |
| F. americana                |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| F. nigra                    |             |    |     |     | 2   |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 2  |    |    |    |    |     |    |    | 34 |
| Ninebark                    |             |    |     |     | 3   | 2  |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 5  | 13 |    |    |    |     |    |    |    |
| Nyssa sylvatica             |             |    |     |     | 1   |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Platanus occidentalis       |             |    |     |     | 2   |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 2  |    |    |    |    |     |    |    |    |
| Populus sp.?                |             |    | 5   | 2   |     |    |     | 2  | 1   | 5   | 1           |    |    |    |    |    |    |    |    |    |             |    | 1  |    |    |    |    |     |    |    | 4  |
| P. deltoides                |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 6  |    |    | 1  | 2  | 8   |    |    | 2  |
| Quercus alba                | 30          | 27 | 56  | 91  | 66  |    |     | 45 | 21  | 114 | 86          |    |    |    |    |    |    |    |    |    |             |    | 55 | 1  | 2  | 8  | 35 | 105 | 67 |    | 48 |
| Q. bicolor                  |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    | 3  |    |    |    |    |     |    |    |    |
| Q. ellipsoidalis            |             |    |     |     |     |    |     |    | 16  | 22  |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    | 3  | 26  |    |    |    |
| Q. macrocarpa               |             |    |     |     |     |    |     |    | 23  | 26  |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    | 6  | 25  | 12 |    |    |
| Q. palustris                | 4           | 2  | 15  | 8   |     |    |     | 40 |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Q. rubra var. borealis      | 15          |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Q. velutina                 |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Yellow oak                  |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Salix sp.?                  | 23          | 24 | 23  | 24  | 25  | 10 | 58  | 22 | 49  | 57  |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Ulmus sp.?                  |             |    |     |     |     |    |     |    |     |     |             |    |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |
| Total stems                 | 76          | 61 | 158 | 251 | 156 | 12 | 149 | 86 | 226 | 217 | 220         | 48 |    |    |    |    |    |    |    |    |             |    |    |    |    |    |    |     |    |    |    |

# DISTRIBUTION OF QUERCUS MUHLENBERGII IN INDIANA\*

By WM. REYNOLDS AND J. E. POTZGER

In a complex forest association such as found in Indiana one is confronted with interesting distribution patterns of some species. These same species may to some degree all associate in the mixed mesophytic forest association. All of them are adapted to the macroclimate but can be segregated from the climax association complex into smaller individual groups by variations of the microclimate. This is determined by physiographic conditions which may modify aerial and edaphic factors. Potzger (5) has discussed this phenomenon as operative in distribution of sugar maple, beech and white oak. Potzger and Friesner (6) referred to it in *Quercus rubra* and *Q. velutina*. All of these segregations are, of course, due to modifications of the macroclimate in more or less limited areas. It is quite obvious that identical soil and physiographic factors in Indiana and northern Michigan, let us say, could not involve segregation of the same genera and species with small variations in the edaphic and aerial factors because of the major selection of species by the macroclimate, or generalized climate, which is greatly different in the two locations.

When control of species is due to multiple factors it is practically impossible to discern the control by customary field methods, even though the response of species is so definite that a sharp line may separate the two types of habitat and the characteristic trees growing there. Over the greater part of Indiana *Quercus muhlenbergii* is a minor associate in the mixed mesophytic forest complex, low in abundance and in fidelity in similar stands. Deam (2) discusses this characteristic of the species when he says, "It is rare or an infrequent tree in practically all parts of its range." While it expresses itself in such manner in most forests of Indiana, it behaves very differently in the Whitewater and the Laughery Creek locations. In this region, especially on south and steep north-facing slopes it plays a very

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\* This is contribution 239 of the Butler University Botanical Laboratory. We thank the owners of the forests studied for permission to carry out the survey on their property.

prominent part in the more mesophytic aspect of the oak-hickory forest type, forming there a *Quercus muhlenbergii*-*Q. rubra* association. This unusual change in the chinquapin oak from subordinate to co-dominant control in the crown cover in a limited geographical location marked by outcrops of Ordovician and Silurian limestone aroused our interest. This study is an attempt to investigate the association more in detail.

## GEOLOGY AND SOIL OF THE REGION

The preferred habitat of *Quercus muhlenbergii* appeared to be slopes with limestone outcrops, for that reason we will consider briefly only the geology of the rock outcrops. While all four counties (Fayette, Franklin, Ripley and Ohio) were influenced by either Illinoian or both Illinoian and Early Wisconsin glaciation, the leached soils of Illinoian as well as the less leached soils of Wisconsin glaciation are apparently closed to the chinquapin oak and some of its associates. The Cincinnati Arch is of great significance in the area because this uplift brought the Ordovician and Silurian limestones sufficiently close to the surface to enable stream cutting to expose them. The soil on the slopes is thin, and slabs of limestone are embedded in the soil or they lie in chaotic profusion on the surface, making walking on the slopes a difficult matter. In places where less fracturing of the strata has taken place solution lines have developed, producing a layered effect in the rock strata. Whitewater River and Laughery Creek are the major control of the cutting action in their own valleys as well as in all small and larger tributary valleys. The geologic history is strikingly similar in the four counties, since all came under the modifying influence of the Cincinnati Arch.

The soils on the slopes are, thus, of post-glacial origin. Long years of leaching has deprived the Illinoian drift of most of its soluble calcium, causing a general acid condition. On the slopes, however, leaching of the limestone outcrops keeps the soils on the alkaline side.

## METHODS

Five stands of forest located in Fayette, Franklin, Ripley and Ohio counties were studied for sociological features on basis of ten, twenty or fifty ten-meter-square quadrats. (These represented at least ten per cent of the stands.) Abundance, frequency index, fidelity and stem-size distribution were stressed (table 3). Only one

stand is given in detail (table 2) ; for all others summaries are presented in table 3. The DBH. measurements were made with wooden calipers. At three stands soil samples were taken at surface and 6-inch levels at frequent intervals up the slope (table 1), and field observations were made on the characteristics of the soil. As a whole, the quadrat studies were limited to that section of the slope where *Quercus muhlenbergii* indicated its preferred habitat. Only the stand near Metamora in Franklin County is shown in detail in table 2 as type for the association.

## RESULTS

*Quercus muhlenbergii* is definitely limited to drier slopes, i.e., south-facing or steep north-facing slopes. It was never found invading ridge-tops, these were occupied by white and black oaks and hickories. Conditions are almost identical at all five stands studied, both as to habitat and forest association. The chief associate of *Quercus muhlenbergii* is *Q. rubra*. Consistently associated in a minor way are several species of *Carya*; *Acer saccharum* and several species of *Fraxinus*. *Ostrya* is without doubt the most characteristic second layer tree. Variations in a minor way are indicated by fluctuations between *Acer saccharum* and *Fraxinus* spp.? or *Quercus alba*. Outstanding by their consistent absence are *Fagus grandifolia* and *Quercus velutina*. *Acer saccharum* shows prolific reproduction but it is usually present only in the small stem sizes. Indirectly this suggests high mortality of the species. The characteristic habitat of the *Quercus muhlenbergii*-*Q. rubra* association is marked by alkaline soil. The limits of presence of these species of oak harmonize strikingly well with decrease in alkalinity.

Acidity of soil follows a rather uniform pattern, i.e., the zone where the Chinquapin oak thrives best is medium acid at one station (Swain woods) to highly alkaline in all other stands. Differences in acidity between surface and six-inch soils are small, perhaps not greater than one would expect in multiple samples at the same zone. That the five stations are not identical in habitat factors is indicated by greater or lesser abundance of mesic or xeric associates. More moisture on the steep north-facing slope (compared with south-facing slopes of the region) where the Harting woods is located is indicated by the prominent participation of mesic *Acer saccharum* in the crown control.

## DISCUSSION

Very frequently one reads of assumptions that oak-hickory necessarily also refers to xeric conditions in the habitat, but this is not quite correct. Among the oaks *Quercus alba* (to a lesser degree), *Q. rubra* and *Q. muhlenbergii* appear to be just a little less mesophytic than *Acer saccharum*. While *Quercus alba* is facultative, *Q. velutina*, *Q. montana* and others are obligative indicators of xeric habitats. In the counties included in this study, we seem to deal with an intermediate condition of moisture between the mixed mesophytic climax and oak-hickory habitat sites. In this habitat acidity may constitute a selective factor. As for *Quercus muhlenbergii*, light may operate as an inhibiting factor in the mixed mesophytic forest. In most extensive quadrat studies by Potzger (5) in Monroe County, and by Potzger and Friesner (6) in Monroe, Brown, and Bartholomew counties *Q. muhlenbergii* never appeared at all or just occasionally, but never as dominant. In these same counties *Q. rubra* seldom participated as associate in the oak-hickory forests, but was a frequent co-dominant in the mixed mesophytic climax. Of course, the rock outcrops in these counties are not the pure limestone as those in the Laughery and Whitewater valleys. They are also not arranged as slabs overlying one another as in the Ordovician and Silurian outcrops in eastern Indiana. This slab arrangement may permit accumulation of seepage water along the fracture lines and thus make it a less xeric habitat than that on slopes where the Borden outcrops.

Habitat controls of forest types are never very easy to discover or to analyze definitely, since multiple factors are underlying. This is especially true when a species of customary minor importance in the association segregates and then expresses itself as an important dominant in a modified aggregate of species from both mesic and xeric habitats. In the present instance it involves *Quercus muhlenbergii*, *Q. rubra* and species of *Fraxinus*, *Carya* and to a lesser degree also *Acer saccharum*, in the region of Ordovician and Silurian limestone outcrops along south-facing slopes. Involuntarily one wonders what the difference might be in these habitats and those of other parts of the state. Auten and Blair (1) say, "Soils affect trees principally through soil air and soil moisture. Seasonal available soil moisture often determines what species will be found in a given forest and their rate of growth."

Such a conclusion may be correct in a general way for trees in agreement with a particular climate, but even in such locations there must be other edaphic factors which limit plant ecesis, especially also as these factors affect germination of the seeds and the seedling stage, or perhaps even absorption of the mature tree. Palmer (4) discovered that *Lemanea* in Indiana streams was obligatively limited to limestone outcrops of Silurian, Devonian and Upper Mississippian, but he never found the plant on Ordovician outcrops. He was not able to determine the cause of such control which limited growth of the alga to these particular limestone outcrops but he thought that it was the presence of small amounts of certain chemicals in the water dissolved out of the limestones.

From the field observations we can definitely say that *Quercus muhlenbergii* and its associates seem to function as a unit, in agreement with the particular type of habitat which was described in an earlier section of this article. The habitat is apparently too dry for *Fagus grandifolia* and too moist for *Quercus velutina*. Nine of the 14 most common associates show 100 per cent fidelity (table 3), and more species show a high per cent F. I. than would be expected according to Raunkiaer's statement of the law of distribution of species in an association. It is also true that the association follows lines of high alkalinity of soil. However, alkalinity per se, or its influence indirectly on absorption of minerals with its subsequent influence on ecesis of the species represented the field study alone cannot determine. According to the Dominion Forest Service in Ontario (3) *Quercus muhlenbergii* is limited in Ontario, too, to limestone outcrops. As for soil moisture, it appears that the shingled character of the rock strata and loose boulders may retard runoff more effectively than the Borden of Brown and Bartholomew counties. This might well result in an intermediate condition between the habitats controlled by the mixed mesophytic forest association, on the moist side, and the oak-hickory (black and white oaks) on the xeric side.

## SUMMARY AND CONCLUSIONS

1. The study is concerned with five stands of forest characterized by a *Quercus muhlenbergii*-*Q. rubra* association.
2. The stands are located on south-facing and steep north-facing slopes with Ordovician or Silurian limestone outcrops in the Laughery Creek and Whitewater River valleys in Indiana.

3. Soil within the limits of best development of the association is alkaline.

4. The two species of oaks have a high fidelity and frequency.

5. *Quercus muhlenbergii* and *Q. rubra* contribute 39 to 63 per cent of stems 6 inches or over DBH., which is interpreted as of importance in crown control.

6. Small stem-sizes are less abundant for the two oaks than for many of the associates which play a minor role in control of the crown cover.

7. Both *Fagus grandifolia* and *Quercus velutina* seem to be barred from the association. This suggests a soil moisture condition intermediate between the mixed mesophytic and the black oak-white oak-hickory habitats.

8. Apparently both soil moisture and pH exercise controlling influence on selection of members of the association.

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TABLE I

Soil acidity (pH) in various stands of the *Quercus muhlenbergii*-*Q. rubra* association

| Locations                                    | Surface | 6-inch | Descriptions                                      |
|----------------------------------------------|---------|--------|---------------------------------------------------|
| South-facing slope at Versailles, Ripley Co. |         |        |                                                   |
| 1. Near foot of slope                        | 7.73    |        | Lower limit of <i>Quercus muhlenbergii</i>        |
| 2. Fifty feet above 1                        | 7.68    | 7.88   | Limestone boulders in soil                        |
| 3. 75 feet above 1                           | 7.76    | 7.8    | Among roots of young Chinquapin oak               |
| 4. 150 feet above 1                          | 7.5     | 7.85   | Near upper limits of slope                        |
| 5. In row of <i>Q. velutina</i>              | 6.58    | 6.76   | Upper rim of slope                                |
| 6. <i>Q. alba</i> and <i>Q. rubra</i>        | 6.33    | 5.3    | On upper slope                                    |
| 7. Abundant young <i>Q. alba</i>             | 4.78    | 5.43   | Flat ridge top                                    |
| 8. Bank of creek                             | 8.17    |        | Seepage water                                     |
| Whitewater valley, south-facing slope        |         |        |                                                   |
| 1. Lower slope                               | 7.25    | 7.03   | Lower limit of <i>Quercus muhlenbergii</i> zone   |
| 2. Midslope                                  | 7.8     | 7.48   | <i>Q. muhlenbergii</i> zone                       |
| 3. Top of slope                              | 6.88    | 7.01   | Zone of <i>Q. rubra</i> and <i>Acer saccharum</i> |
| 4. Seepage at foot of slope                  | 7.3     |        |                                                   |
| Fayette County, Stone's Woods                |         |        |                                                   |
| 1. Midslope                                  | 7.7     | 7.96   | <i>Q. muhlenbergii</i> zone                       |
| 2. Above <i>Q. muhlenbergii</i>              | 5.5     | 5.4    | Zone of various species of oaks                   |
| 3. Creek water                               | 6.9     |        |                                                   |
| Franklin County, Swain woods                 |         |        |                                                   |
| 1. Upper limit <i>Q. muhlenbergii</i>        | 6.85    | 6.7    |                                                   |
| 2. Crest of hill                             | 6.15    | 6.05   | No <i>Q. muhlenbergii</i>                         |
| 3. Creek water                               | 7.4     |        |                                                   |

TABLE II

Tabulations of woody species from 50 ten-meter-square quadrats on a south-facing slope into Whitewater valley about 2 miles west of Metamora, Franklin County, Indiana

| Species                       | Below<br>1 in. | 1-2 | 3-5 | 6-10 | 11-15 | 16-20 | Above<br>20 | Total<br>stems | Per cent<br>F. I. |
|-------------------------------|----------------|-----|-----|------|-------|-------|-------------|----------------|-------------------|
| <i>Acer saccharum</i>         | 34             | 350 | 43  | 3    |       |       |             | 430            | 98                |
| <i>Aesculus glabra</i>        | 12             | 24  | 4   | 2    |       |       |             | 42             | 32                |
| <i>Carpinus caroliniana</i>   |                | 2   |     |      |       |       |             | 2              | 2                 |
| <i>Carya cordiformis</i>      | 1              | 10  | 1   | 2    |       |       |             | 14             | 20                |
| <i>C. glabra</i>              |                | 2   | 1   |      |       |       |             | 3              | 4                 |
| <i>C. ovata</i>               | 7              | 35  | 16  | 17   | 8     | 5     |             | 88             | 84                |
| <i>Celtis occidentalis</i>    | 1              | 2   |     |      |       |       |             | 3              | 4                 |
| <i>Cercis canadensis</i>      | 19             | 10  | 2   |      |       |       |             | 31             | 20                |
| <i>Cornus drummondii</i>      | 48             | 2   |     |      |       |       |             | 50             | 20                |
| <i>Crataegus</i> sp.?         | 4              | 3   | 7   | 1    |       |       |             | 15             | 24                |
| <i>Fraxinus americana</i>     | 9              | 29  | 24  | 13   | 1     |       |             | 76             | 66                |
| <i>F. quadrangulata</i>       | 35             | 86  | 20  | 12   | 1     |       |             | 154            | 82                |
| <i>Gymnocladus dioica</i>     |                | 4   |     |      |       |       |             | 4              | 4                 |
| <i>Juglans nigra</i>          |                |     |     | 2    | 1     |       |             | 3              | 6                 |
| <i>Morus rubra</i>            |                | 1   |     |      |       |       |             | 1              | 2                 |
| <i>Ostrya virginiana</i>      | 23             | 58  | 50  | 5    |       |       |             | 136            | 82                |
| <i>Quercus muhlenbergii</i>   | 3              | 18  | 19  | 18   | 6     | 8     | 3           | 75             | 64                |
| <i>Q. rubra</i>               |                | 6   | 20  | 15   | 10    | 3     | 2           | 56             | 64                |
| <i>Tilia americana</i>        |                | 1   | 1   |      |       |       |             | 2              | 2                 |
| <i>Ulmus americana</i>        | 4              | 4   | 7   | 5    | 5     | 2     |             | 27             | 42                |
| <i>U. rubra</i>               |                |     | 1   | 7    |       |       |             | 8              | 14                |
| SHRUBS                        |                |     |     |      |       |       |             |                |                   |
| <i>Euonymus atropurpureus</i> | 5              |     |     |      |       |       |             | 5              | 8                 |
| <i>Dirca palustris</i>        | 7              | 49  |     |      |       |       |             | 56             | 6                 |
| <i>Rhus radicans</i>          | 2              |     |     |      |       |       |             | 2              | 4                 |
| <i>Ribes</i> sp.?             | 19             |     |     |      |       |       |             | 19             | 24                |
| <i>Viburnum prunifolium</i>   | 10             |     |     |      |       |       |             | 10             | 4                 |
| <i>Vitis</i> sp.?             | 9              |     |     |      |       |       |             | 9              | 14                |

TABLE III

Summary of sociological characteristics of 14 species of trees in five stands of *Quercus muhlenbergii*-*Q. rubra* association in Whitewater and Laughery Creek valleys

| Species                     | Per cent of total stems 6 inches or above DBH. |      |      |      |      | Per cent F. I. |    |     |     |     | Average number of stems per 10-meter quadrat 5 inches or less DBH. |     |      |      |      | Fidelity |   |   |   |   |
|-----------------------------|------------------------------------------------|------|------|------|------|----------------|----|-----|-----|-----|--------------------------------------------------------------------|-----|------|------|------|----------|---|---|---|---|
|                             | A                                              | B    | C    | D    | E    | A              | B  | C   | D   | E   | A                                                                  | B   | C    | D    | E    | A        | B | C | D | E |
| <i>Quercus muhlenbergii</i> | 36.7                                           | 22.3 | 16.2 | 41.0 | 16.6 | 90             | 64 | 60  | 100 | 70  | 2.3                                                                | .8  | 1.8  | 5.1  | 7.2  | x        | x | x | x | x |
| <i>Q. rubra</i>             | 26.5                                           | 19.0 | 31.0 | 13.7 | 22.2 | 90             | 64 | 85  | 60  | 60  | .4                                                                 | .5  | .8   | 1.0  | .4   | x        | x | x | x | x |
| <i>Q. alba</i>              |                                                |      | 28.3 | 26.0 |      | 20             |    | 55  | 60  |     | .3                                                                 |     | 1.9  | 2.7  |      | x        | x | x | x |   |
| <i>Carya ovata</i>          | 19.0                                           | 6.7  | 2.7  | 8.3  |      | 70             | 84 | 50  | 55  | 40  | 1.9                                                                | 1.1 | 1.1  | .3   | .5   | x        | x | x | x | x |
| <i>Fraxinus americana</i>   |                                                |      |      |      |      |                |    |     |     |     |                                                                    |     |      |      |      |          |   |   |   |   |
| <i>F. lanceolata</i>        | 1.0                                            | 8.9  | 2.7  | 4.0  | 8.3  | 90             | 66 |     | 90  | 90  | 2.6                                                                | 1.2 | 1.4  | 1.7  | 3.3  | x        | x | x | x | x |
| <i>F. quadrangulata</i>     |                                                | 8.2  |      |      |      | 30             | 82 | 35  | 60  | 90  | .4                                                                 | 2.8 | .7   | 1.7  | 3.3  | x        | x | x | x | x |
| <i>Acer saccharum</i>       |                                                | 1.9  | 4.0  | 2.7  | 31.0 | 90             | 98 | 100 | 100 | 100 | 8.9                                                                | 8.5 | 27.0 | 21.4 | 9.0  | x        | x | x | x | x |
| <i>Aesculus glabra</i>      |                                                | 1.3  | 4.0  |      | 5.5  |                | 32 | 20  | 40  | 50  |                                                                    | .8  | .1   | .3   | .5   | x        | x | x | x | x |
| <i>Carya cordiformis</i>    |                                                | 1.3  | 1.3  |      |      | 60             | 20 | 50  | 20  |     | 1.6                                                                | .2  | .5   | .3   | .5   | x        | x | x | x | x |
| <i>C. glabra</i>            | 4.0                                            |      |      | 6.8  |      | 50             | 4  | 25  | 45  | 30  | 1.2                                                                | .1  | .8   | .2   | .4   | x        | x | x | x | x |
| <i>Ulmus americana</i>      |                                                | 7.6  |      |      |      |                | 42 |     |     |     |                                                                    | .3  |      |      |      | x        |   |   |   |   |
| <i>U. rubra</i>             | 12.2                                           | 4.5  |      |      |      | 90             | 14 | 55  |     |     | 12.1                                                               |     | 2.6  |      |      | x        | x | x |   |   |
| <i>Carpinus caroliniana</i> |                                                |      |      |      |      | 30             | 2  | 10  | 15  | 10  | 1.0                                                                |     | .1   | .4   | .2   | x        | x | x | x | x |
| <i>Ostrya virginiana</i>    |                                                |      |      |      |      | 100            | 82 | 85  | 100 | 100 | 9.0                                                                | 2.6 | 4.9  | 7.5  | 10.3 | x        | x | x | x | x |

# PINUS VIRGINIANA IN THE FOREST PRIMEVAL OF FIVE SOUTHERN INDIANA COUNTIES

By MILDRED I. ROSS

## INTRODUCTION

The numerous misconceptions of the primeval conditions in our country plainly show that the most common knowledge of an environment may become less than a half-truth by the time a second generation of men lives in that same area. New environmental conditions bring out the hidden potentialities of plants and animals and gradually men formulate new concepts and believe that they are describing the organism under primeval conditions. It is, of course, amazing how very little man placed on record about the things with which he was associated when he came into the wilderness where life was controlled by natural laws. This is true for accurate descriptions of the flora and the fauna of Indiana forests, of the prairies, of the relic colonies of northern and southern plants, and, in this case, of the presence of one particular species of pine.

*Pinus virginiana* in a deciduous forest must have been conspicuous enough, and it must have been of definite economic importance to Indians and pioneers alike, yet knowledge of its presence when white men came is now so veiled in obscurity that some men doubt that it was ever native in the forest primeval of Indiana.

The opinion of so-called pioneers quoted by Deam (4) is inadequate as an answer to the question because they were too far removed from the undisturbed primeval forest. For that reason the present study was undertaken, using as source of information, data obtained from records which greatly antedate the changes in primeval conditions brought about by the activities of civilized man.

## PINUS VIRGINIANA AND ITS DISTRIBUTION

*Pinus virginiana* is known under a variety of names, such as "old field pine," "Jersey pine," and "pitch pine." The latter is the name preferred by the pioneers. Green (7) says, "In the south it is known as 'possum pine' because of its dark, discouraged-looking branches."

Another very common name is "scrub pine," referring to the characteristic that even after death the side branches persist for many years, giving the tree a ragged, scrubby appearance.

Potzger (14) says, "It is found in the open fields, along roadsides, in pastures, ditches and fence corners." *Pinus virginiana* produces seeds abundantly. Sargent (17) says, "Cones develop most prolifically on exposed branches." Later on he says, "Seed production is most prolific, at least three-fourths of the cones bearing well developed seeds, and as many as 75 seeds to the cone were counted." Likewise, Deam (4) states, "It propagates easily from self sown seeds." Thus *Pinus virginiana* was ideally equipped to take control of many open areas under primeval forest conditions. It was necessarily limited in extent, being found on the crowns of knobs. The early pioneers made numerous ideal situations for the spread of pine, not only on the knobs along the Ohio River, but over a wide area in Indiana where the soil became impoverished by poor conservation practices.

The pattern of distribution of Virginia pine in the United States is roughly triangular in shape, as shown by Livingston and Shreve (12). The base of the triangle extends from Long Island and the sandy barrens of New Jersey to central Georgia. However, it is generally excluded from the coastal plain from Virginia to Georgia. The range extends westward over shale hills and mountain bases across the Alleghenies, terminating in Kentucky and the knobstone areas of Floyd, Clark, Scott and Washington counties in southern Indiana. Collingwood (3) says that its vertical gradient is from sea level to three thousand feet, but that it attains its largest size in the low hills and knobs of southern Indiana.

There is no doubt that *Pinus virginiana* occupies a unique position in forest distribution. Livingston and Shreve (12) have selected it as a representative type of unusual distribution. They say the following, "*Pinus virginiana* has been used as an example of a type of distribution which is somewhat unusual among evergreen needle-leaved trees, occupying an area between the northern and southern evergreen needle-leaved forests and lying wholly within the deciduous region." A comprehensive study of *Pinus virginiana* in Indiana was made by Deam (4). We quote him as follows, "The distribution in Indiana is quite limited and has never been fully understood by authors who

variously give it as found throughout the southern part of Indiana. It is confined to the knob area of Clark, Floyd and Scott counties and the southeastern part of Washington County. In the original forests it is confined to the tops of the knobs where it is associated with *Quercus prinus* (Gray's Man. 8th ed.). It propagates easily from self-sown seed, hence is soon found on the lower slopes of cut-over lands and soon occupies fallow fields. It is now found in the open woods several miles east of the preceding counties, but pioneers of this section say that it was not a constituent of the original forests but has come in since the original forests were heavily cut over. It is believed that it crowned the knobs over an area from 5-10 miles wide extending through the counties named and extending northward about 25 miles."

According to DenUyl (5), civilized man has extended the range of *Pinus virginiana* in Indiana by frequent planting on farmsteads and school and church grounds in southern Indiana. From these planted trees natural regeneration has occurred. It is now found in 29 counties not listed by Dr. Deam.

## GEOLOGY AND PHYSIOGRAPHY OF THE REGION

The area under consideration in southern Indiana is as a whole rugged, though notable exceptions occur, especially along the Ohio River where a plain has developed. The peak of relief is reached in the unglaciated portion of Floyd, Clark and Scott counties. Much of the region bordering the Ohio River has striking relief due to the cutting of the river. It is here also, that the largest, most prominent and well defined topographic form in Indiana, the Knobstone Escarpment, starts. This range of hills extends northward from the Ohio River for nearly 150 miles. Near the river it is rugged in appearance due to the many small streams which descend from the upland back of the crest which rises 400 to 600 feet above the lowlands and valleys below. "Prominences on this in Floyd, Washington, Clark and Scott counties," says Malott (13), "reach an altitude of over 1,000 feet." Everywhere the escarpment is steep-sloped, but rarely, if ever, unscalable. At places where the face is broken and dissected the prominent spurs appear from the distance as great knobs and conical hills. These are spoken of as "The Knobs."

## PIONEERS AND PIONEER SETTLEMENTS

The vast wilderness of which southern Indiana constituted a part was, at the time of the Revolutionary War, the favorite hunting ground of various Indian tribes. No real effort had been made by white men to settle it. After the end of the war, George Rogers Clark and men of his command received a grant of land (Clark's Grant) from the government. Being open for immediate occupation, many of the men and their families started there soon after. One of the first problems after reaching the new land was the location of a suitable place for a community.

At the falls of the Ohio River, a town site was laid out, and in 1783 Clarksville came into being. It is the oldest settlement in southeastern Indiana on the Ohio River. Only the most hardy and brave dared come into the wilderness to settle here for the Indians used all their cunning to kill and terrorize the white man. The process of taking up lands was necessarily slow, but by 1795 a second community had been established off the Ohio River. To it, Springville, goes the distinction of being the first "All American" town in the new grant not located on the River. Slowly at first, but with ever increasing tempo, the tide of immigration moved south and west, striking the other counties in southern Indiana under consideration as follows: Switzerland—1795; Floyd—1799; Scott—1805; and Jefferson—1805.

### HISTORICAL REFERENCES TO PINUS VIRGINIANA IN INDIANA

In order to know definitely whether the scrub pine was a constituent of the forests along the Ohio River when white men first arrived, one must of necessity consult historical records of earliest pioneer life in that region. Pine and its products would have had so many uses for pioneers that they could hardly have failed to make mention of them if the tree was actually present. This assumption proved to be correct, for frequent and specific reference to pine was found both in the field notes of the surveyors and in the description by the pioneers. The use of pine was both varied and extensive. Levering (11) says, "Pine boughs were laid across webbing attached to the sides of a bed in order to provide a comfortable place in which to sleep, since the pioneers had not brought featherbeds." In another reference, she says, "Fire hunting the deer was a favorite way

of killing it. The hunter would go along the stream in his canoe with a pine knot flaming at the bow. When the deer came down to the water's edge to drink or to the salt licks found frequently near the water, the light would shine in its eyes and it would stand immobile, an easy target for the hunter." Collingwood (3) makes the following statement: "The early settlers burned this wood (pine) in kilns to obtain charcoal and tar." Dunn (6) in telling of the domestic needs of the Indians says that they made maple sugar in sugar troughs. "The joints of these (sugar troughs) and their canoes were stopped with gum from evergreen trees and beeswax." Another interesting reference to the use of pine was taken from the History of the Ohio Falls Cities (9). Daniel Boone and his hunters of Kentucky were in the Ohio River country when one of them was captured by the Indians. He was to be burned at the stake. Bogart (10) says, "The Indians had collected their fagots from the pitch pine. . . ." The same author states, "The settlers found, as had the Indians before them, that the evergreens gave forth their resins easily if burned in a kiln. This was used to seal the joints of their canoes to make them leakproof and seaworthy."

The field notes of the surveyors with reference to pitch pine were terse and to the point. Just to quote a few of these: "Third rate soil, covered with pitch pine"; "Soil poor, hilly, pitch pine"; "Broken low ridges, covered with cedar and pine"; "Pitch pine, third rate soil, mountainous."

The names, "Borden's Pine Knob" and "Piney Point," appear in records of the Ohio River country. Since objects are usually named by the first person to see them and are usually somewhat descriptive, in all probability the pioneers were the first whites to see these two points. Surely they must have been the ones who named them. High, conspicuous peaks bearing pine would likely have the word "pine" in any name given them. Thus, Piney Point and Pine Knob would be good names for such points. These statements all refer to the conditions in the forest primeval in certain areas in southern Indiana, and to well established practices of Indians and the earliest white settlers prior to 1807.

## METHODS

In a study interested primarily in facts, mere descriptions about trees and forests are never so reliable as an actual listing of trees,

together with diameter measurements. For that reason, the original United States Land Survey records and the descriptive field notes for Floyd, Scott, Switzerland, Clark and Jefferson counties were used as a basis of study. In the counties mentioned, the surveys were made between 1799 and 1809. At every section and quarter section corners, two witness trees were recorded by their common names, together with their DBH. The listed stems were tabulated as tables I-V in the original thesis, all of which are summarized as table I in the present paper.\* All species named in the surveys were listed to show the forest association and some of the more obvious conditions with which Jersey Pine had to compete in its struggle for survival.

## RESULTS

Details of the forest composition in the counties under study are shown in summarized form in table I. Pine is recorded in only Floyd and Clark counties. The small total of fourteen stems constitutes the record. The stems ranged from 6 to 15 inches DBH. The most abundant tree of the forest association was beech and the most prominently associated with it were sugar maple (*Acer saccharum*), hickories (*Carya spp.*) and tulip poplar (*Liriodendron tulipifera*).

## DISCUSSION

The real reason for distribution patterns of plants is frequently difficult to discover, for both climate and soil may play a part, either separately or jointly. The problem is especially difficult in the case of *Pinus virginiana* because of the wide range of climate it apparently finds suitable to its needs, as Livingston and Shreve point out (12). The most logical assumption as to the cause of such a distribution pattern is that edaphic and light factors may contribute the major controls. Literature makes reference to several characteristics of the scrub pine that may play a part in its distribution range. Potzger (5) and Sargent (17) point out that while this pine is a prolific reproducer it has the weakness of being very intolerant. This weakness at once eliminates it as a competitor in a broad-leaved forest. Such a forest covered all the favorable sites in Indiana at the turn of the 19th century. The climate of southern Indiana makes possible development of a deciduous forest because of ample rainfall, favorable

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\* The original thesis is on file in the Butler University library and is available on loan therefrom.

temperature conditions, many sunny days and moderate evaporation. Recorded data (table I) shows that it was forest, composed chiefly of beech, sugar maple, oaks and tulip poplar, and associated with them were other species of broad-leaved trees. In the light of these facts, one wonders how this pine could have established itself in a broad-leaved forest. It is also not surprising that the pioneers of a later date assumed that the Jersey pine had been brought in by the first settlers and represented an escape from a few planted trees.

The points discussed in the previous paragraphs do not represent the whole story, for soil factors, too, play a part in the ability of the tree to establish itself and meet competition. Potzger (14) pointed out that Virginia pine grows well in the poorest soil. Such soil was not wanting in the counties along the Ohio River. The surveyors made frequent reference to the fact that the soil was shallow and poor, especially on the steep slopes and high cliffs along the river. The settlers made similar observations and commented on it.

Poor soil and steep slopes are usually not favorable to the establishment of a dense broad-leaved forest. Open stands or scrubby growth with abundant light filtering through the poorly developed crown cover would favor establishment of light-demanding species. Such a condition was ideal for an intolerant species like *Pinus virginiana*. It could grow here, but it could not invade the lowlands nor the upland flats where a deciduous forest presented a closed crown cover.

The area, then, in which this pine could establish itself was very limited. In a rugged topography such as one finds in the Knobs area, there were always open places, mainly along the outer rims and slopes of the hills. Weathering rock and soil provided many cracks and small crevices in which a species like the scrub pine could gain a foothold and maintain itself. Shade here is greatly eliminated as a control factor. Seedlings received the necessary south-slope sunlight and there they could multiply rapidly. This would not be possible under a canopy of broad-leaved trees controlling crown cover on the flats.

Thus there is no denying that in the Ohio River counties limited habitat sites were ideal for a species with the characteristics of the Jersey pine. Historical accounts definitely describe the presence of the tree in such limited areas. The fact that the Indians were well

acquainted with it and used it in many ways and later taught the white man these uses, is almost conclusive proof that the pine antedates the coming of civilized man. As conclusive proof that *Pinus virginiana* was a constituent in the forest primeval of southern Indiana at the time the settlers came, we have records by the surveyors, of stems 12 to 15 inches DBH. Potzger (15) estimates that it would take approximately 60 years for Jersey pine to grow 15 inches DBH. In other words, the 15-inch DBH tree would have been a seedling in 1747, or antedating by many years the arrival of the first settler.

All these voluminous records point conclusively to the fact that Virginia pine was a component in the forest primeval of southern Indiana. The fact that the surveyors did not record it in Scott County, where Dr. Deam lists it as native, may mean that *Pinus virginiana* extended its range into adjacent counties after civilized man cut the dense broad-leaved forest, or that the line of distribution was so narrow that the trees escaped the large-meshed survey net. Since there is no specific need to discuss in detail the broad-leaved forest primeval against which *Pinus virginiana* had to compete, it may suffice to point out that it was a typical mixed mesophytic forest in which beech and sugar maple usually played the leading role by way of abundance. However, here as in central Indiana, as reported by Potzger and Potzger (16), local habitat factors may at times find expression in a forest association constituted chiefly of oaks and hickories.

## SUMMARY AND CONCLUSIONS

1. The study concerns itself with the problem of whether or not *Pinus virginiana* was a component of the primeval forests of Clark, Floyd, Scott, Jefferson and Switzerland counties, Indiana.

2. Sources of information on the question were the surveyors' field notes and records of witness trees in the original United States land survey made in these counties between 1799 and 1809, and historical accounts of early pioneer life in the area.

3. From the evidence on hand, it is concluded that *Pinus virginiana* was present along the Ohio River in at least Floyd and Clark counties when the pioneers arrived.

4. Historical reports definitely state that the pioneers learned to use pine and products from it for various purposes. Statements

are also made that the Indians knew the pine and used it in various ways.

5. In the survey records, only a few stems are reported, but stems up to 16 inches DBH were included. Growth to such diameter represents at least 60 years of growth, antedating the coming of the pioneers by at least 40 years.

### ACKNOWLEDGMENTS

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TABLE I

Genera and species cited as "witness trees" in Clark, Floyd, Jefferson, Scott and Switzerland Counties

| Species                  | Clark | Floyd | Jefferson | Scott | Switzerland | Total |
|--------------------------|-------|-------|-----------|-------|-------------|-------|
| <i>Acer saccharum</i>    | 26    | 49    | 218       | 32    | 172         | 497   |
| <i>Fagus grandifolia</i> | 311   | 273   | 1049      | 446   | 255         | 2334  |
| <i>Fraxinus</i> spp.     | 39    | 28    | 88        | 19    | 96          | 270   |
| <i>Carya</i> spp.        | 51    | 57    | 128       | 39    | 124         | 399   |
| <i>Quercus alba</i>      | 169   | 141   | 144       | 82    | 139         | 675   |
| <i>Q. velutina</i>       | 79    | 73    | 25        | 17    | 20          | 214   |
| All other <i>Q.</i> spp. | 125   | 33    | 100       | 28    | 14          | 300   |
| <i>Liriodendron</i>      | 51    | 50    | 80        | 34    | 20          | 235   |
| <i>Juglans</i> spp.      | 11    | 17    | 36        | 3     | 11          | 78    |
| <i>Ostrya virginiana</i> | 4     | 5     | 18        | 6     | 17          | 50    |
| <i>Pinus virginiana</i>  | 6     | 8     | 0         | 0     | 0           | 14    |
| <i>Ulmus</i> spp.        | 21    | 9     | 77        | 26    | 58          | 191   |
| All other spp.           | 150   | 131   | 302       | 106   | 273         | 962   |
| Total Stems              | 1043  | 874   | 2265      | 838   | 1199        | 6219  |

# POLLEN ANALYSIS OF A PEAT DEPOSIT IN LIVINGSTON COUNTY, ILLINOIS

By CHARLES DONALD GRIFFIN<sup>1</sup>

This study essays to compare, and in some degree to supplement, pollen analyses thus far published for Illinois. Even though results of studies of fossil pollens seem very similar, each pollen profile is individual and varies in many details from all other profiles. For this reason, each new analysis is more than a repetition of what has already been studied and reported; it is a possible verification of these previous studies and a valuable supplement to the growing science of pollen analysis. It is hoped that the preliminary study of fossil diatom valves found in this deposit can be correlated with the fossil pollen record, and possibly reveal valuable additional data in the quest for information on the history of the pond and of climates of its vicinity.

Turtle Pond is situated in Livingston County, only a few miles from Chatsworth Bog which has been studied by Voss (22). Its exact location is in the southeast corner of Sec. 33, T. 26 N, R. 8 E. Since this was the only peat deposit in eastern Illinois which had been studied, it was considered of interest to make a comparison of the two.

## PROCEDURE

The depth of Turtle Pond is 24 feet. Samples of the peat and sediments were obtained by means of a Hiller peat borer. The samples were taken at 12-inch intervals, placed in one-ounce vials, capped, labelled, and prepared for microscopic examination according to the Geisler alcoholic method (9). Identification of the fossil pollens were made from Wodehouse (23), Erdtman (6), and from prepared slides of modern pollens. At least 150 grains of the large trees were tabulated for each level unless the pollen frequency was exceptionally low. The percentage expressing relative abundance of a given genus (or species) is based either upon the first 150 or more grains encountered, or upon all grains found in ten slides.

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<sup>1</sup> A portion of a thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Botany in the Graduate College of the University of Illinois, 1950.

Valves of diatoms were abundant in this same material. The possibility of finding correlations between pollen profiles and diatom profiles suggested itself, even though effects of environmental changes upon the pond and upon the surrounding land areas might not show any considerable degree of parallelism. In order to find out whether any parallelism exists, diatoms in the slides examined for pollen counts were likewise identified and tabulated.

Because of their small size, the diatoms were studied with 10x oculars and a 90x oil immersion objective. Close to 100 valves were tabulated for each level except in certain levels with very low diatom frequency. The diatom percentages and frequencies are displayed in table IV.\* The diatoms were identified from Boyer (2, 3), Elmore (5), Hustedt (14), Van Heurek (21), Smith (18), and Wolle (24).

## RESULTS

The results of the pollen study are shown graphically in fig. 1 and in tables I and II. Examination of the graph reveals an early dominance by the pollens of the coniferous trees in the lower levels of the sediment. The 23- and 24-foot levels are devoid of pollen but the 22-foot level reveals a few grains. In the 21-foot level, there is a sudden appearance of coniferous pollens and in the 20-foot level there is a great increase in the pollen frequency.

*Picea mariana* is the most abundant species in the lower levels and *P. glauca* is next. *P. glauca*, however, shows its highest percentage of abundance at a point of high pollen frequency (18-ft. level) while the maximum percentage for *P. mariana* comes after that of *P. glauca* (in relation to sediment accumulation and during a time when the pollen frequency is declining (15-ft. level)).

Species of *Pinus* are poorly represented in the lower levels, although *P. strobus* has its second highest percentage at the 20-foot level. It may be pointed out that the pollen frequencies were so low at the 1- to 5- and 21-foot levels that, although percentages were tabulated and charted, they are probably unreliable. To the extent that

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\* Because of expense involved, tables of the original thesis are not here published. They may be consulted in the thesis which is on file in the University of Illinois library.

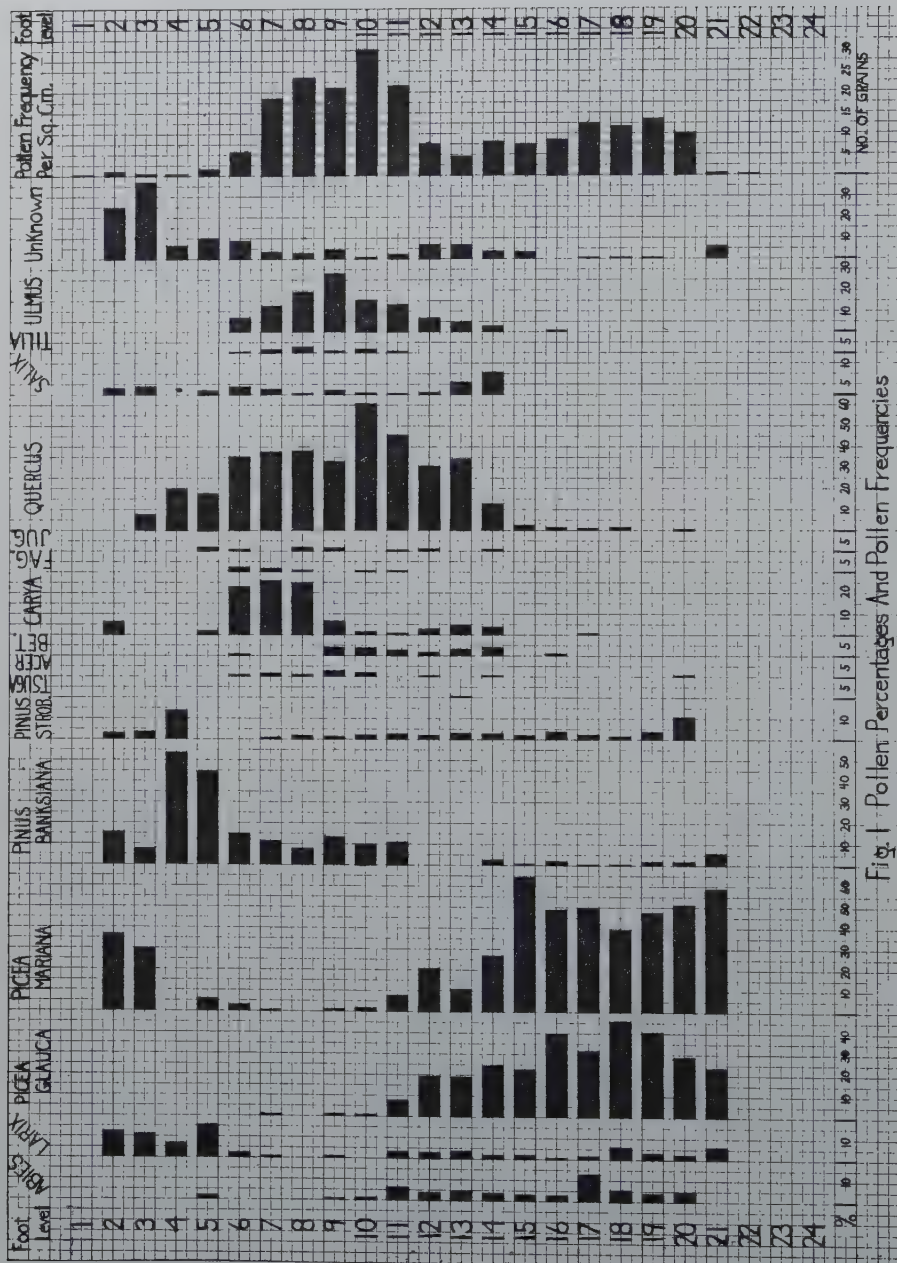


Fig. 1 Pollen Percentages And Pollen Frequencies

these counts are reliable, it may be of significance that *P. banksiana* reached a maximum of 54% at the 4-ft. level when the broadleaf genera were represented only by *Quercus* (20%) and that this followed a second prairie invasion as shown by high frequency of grass and chenopod pollens during the 7- to 5-ft. levels. *Larix* is more frequent in the lower levels than in the upper. *Abies* shows a maximum percentage at the 17-foot level. After the maximum for *Picea mariana* at the 15-foot level, there is a rapid decline in the coniferous pollens and a striking increase in those of the broad-leaved genera (especially *Quercus*).

There is a great increase in the number of grass, chenopod and willow pollens in this zone of transition (14-13-foot levels) between dominance by conifers and dominance by broad-leaved genera, as may be seen in fig. 1 and table II. There is also a decrease in pollen frequencies during this interval. Above the 13-foot level there is a great increase in pollen frequencies with almost complete disappearance above the 11-foot level of coniferous pollens (except for a rather uniform representation of *Pinus*) followed by increase in oak, elm, hickory, and linden.

The highest pollen frequency occurs at the 10-foot level. This is the level of oak maximum. Mollusk shells and pollens of *Nymphaea* were also observed at the 10-foot level. From the 10- to the 6-foot level, pollen frequencies decline. This decline is almost wholly that of broad-leaf tree pollens. The maximum for *Ulmus* is at the 9-foot level, while *Carya*, sparingly present from the 14- to 9-foot levels, is well represented (surpassed only by *Quercus*) at the 8-, 7-, and 6-foot levels.

At the 6-foot level, there is a second occurrence in considerable numbers of grass, chenopod, buttonbush, and cattail pollens. Thus at two depths, one in the interval of conifer decline and broad-leaved increase and the other just after the decline of broad-leaved genera, there is a maximum pollen representation for shrubs and herbs. *Tsuga*, *Acer*, *Betula*, *Fagus*, and *Juglans* are sparsely represented by pollens and appear with the dominant broad-leaved *Quercus*, *Carya* and *Ulmus*.

The results of the preliminary diatom counts are shown in table IV. This table shows the percentages of diatoms located in each foot level

and the diatom frequency per square centimeter in each foot-level. It can be seen that some species are more frequent at one level than at another and that some species are present only in certain levels or series of levels.

## SIGNIFICANCE OF THE RESULTS

Comparison of profiles of Turtle Pond and Chatsworth Bog show that they are quite similar in composition of pollen. Excluding the upper 5 feet and lower 4 feet from the Turtle Pond boring (in which the pollen frequencies are very low and results unreliable), there are 15 feet of peat that can be favorably compared with the Chatsworth. In both locations, the lower levels indicate a cool moist climate at the beginning of pollen accumulations after the retreat of the ice from this area. This is presumed because of the abundance of conifer pollens, especially of *Picea*. There is an initial maximum in pollen frequency of both bogs during this coniferous period. This pollen-count maximum for all species represented holds from the 19-foot through the 17-foot level at Turtle Pond. A decrease from the 16- to 13-foot levels is followed by a second increase, this time in deciduous-tree pollens, with highest pollen count at the 10-foot level. A decrease in pollen frequencies also occurs in the Chatsworth profile between the initial conifer abundance and an abundance of deciduous-tree pollens.

There is no indication (due to lack of herbaceous pollens) of a tundra vegetation having invaded this area shortly after the waning of the ice. However, with decrease of the conifer pollen and the corresponding decrease in pollen frequency, Voss reports, for the Chatsworth Bog, that *Ambrosia* pollen is exceedingly abundant. Similar results were obtained at Turtle Pond, in which, at this level of low pollen frequency, there appears a high percentage for herbaceous pollens (table II). Voss discounts the possibility that the *Ambrosia* pollen may indicate a drier period than the preceding period of conifer dominance. Preservation of *Ambrosia* pollen was attributed to a greater resistance to decay. He interpreted vegetational change in Illinois as merely a gradual change from conifer to broad-leaved genera. The present study suggests a somewhat different interpretation.

The Turtle Pond profile tends to substantiate the occurrence of two xeric periods in which there were fewer trees and many shrubs.

It is concluded that this part of Illinois was twice invaded by herbaceous species forming a prairie over a sizeable proportion of the general area. The conifers, south of the ice margin, had presumably advanced northward after the retreating Wisconsin ice and, due to consequent drier and warmer conditions, the coniferous forest was at least over part of its area replaced by prairie vegetation. This is one of the vegetational changes suggested by Gleason (11) from other evidence. If this conclusion is correct, the area of herbaceous cover was later, in part, re-invaded by forest, but this time by trees of the deciduous species. The gradual entrance of deciduous species began at the same time that conifers began their decline (the 14-foot level at Turtle Pond). Decline of conifers was nearly complete (at the 11-foot level) before the broadleaf pollen maximum (10-foot level). These facts by themselves conform to Voss' idea of gradual change from conifers to broadleaf genera. If, however, there had been no diminution in forest coverage, we should similarly find no diminution in pollen frequency in the period represented by 16- to 12-foot levels. The minimum pollen count is at the 13-foot level. This long period of low tree-pollen counts coincides with the first maximum for pollens of grasses and chenopods (see table II). There seems to be little reason for doubting the possibility that prairie could have occupied much of the area during this period. The second increase of prairie presumably accompanies the decline of deciduous pollen in the 7- to 5-foot interval. The upper part of the profile (1- to 5-foot levels) is not dependable since near-surface conditions in recent times may have destroyed pollens originally present. Certainly, the herbaceous cover was in nearly complete possession of this central part of the Illinois Grand Prairie at the time of immigration of the first Europeans.

Several climatic interpretations of the Turtle Pond pollen profile may be assumed. It is evident that changes in the vegetation-types, which at successive times contributed the largest quota of pollens, were from conifers, to herbs, to broadleaf tree genera, to herbs. A major distinction between grassland and forest, as reported by Transeau (20), is based largely upon difference in available moisture and its seasonal distribution. Pollens from a combination of coniferous genera suggest cooler climate than from a combination of broad-leaf tree genera. The climatic stages indicated by the pollen

profile are thus: cool-moist, to warm-dry, to warm-moist, to warm-dry.

From the work of various Scandinavian botanists and geologists, there has been established the Blytt-Sernander hypothesis of the succession of postglacial climates. This scheme applies specifically to northwestern Europe, although the basic climatic changes it implies are common to a far wider range (Flint, 7). The similarity of this hypothesis to the climatic sequences represented by the Turtle Pond pollen profile is striking. The suggested correlation is represented in table II. The significance of high pollen percentages for *Typha* and *Cephalanthus* at the 6-foot level is not readily determined. Possibly the water level of the pond became lower at this time, thereby exposing a greater area favorable for extensive development of these genera. Due to low pollen frequencies in the 1- to 5-foot levels and the absence and sparseness of pollens in the 22- to 24-foot levels, no direct correlation of these levels can be made with the Blytt-Sernander phases. The arctic phases in Europe are correlated with the appearance of pollens characteristic of tundra plants. As stated previously, no evidence of tundra is found in Turtle Pond.

It is difficult to correlate climatic changes indicated in the pollen profile with the Wisconsin glacial substages. Turtle Pond is located on drift of the Tazewell substage. If succeeding substages, the Cary and Mankato, were initiated with major climatic changes, these should be recorded in the profile. However, the truncated records of Turtle Pond and Chatsworth Bog may not include climatic changes during each of these substages. Further pollen analyses are needed from this area to substantiate a more definite relationship between vegetational and climatic (glacial) history.

Woodward (25) presents an interesting discussion on the presence of tundra next to the ice front. Although the present study gives no support for this supposition, it is not entirely unlikely, since the lower levels of the sediment reveal neither spores nor pollen. This could be due to unfavorable conditions for the preservation of microfossils at this time or to the possibility that this "kettle hole" was not an open stand of water immediately following the ice retreat. Pollen spectra in North America, unlike those of Europe, have not shown evidence of tundra vegetation at the beginning of sediment accumulation in the bogs.

Comparing Turtle Pond with bogs on Early Wisconsin (Tazewell) drift in Indiana, several similarities are noted. One is the sparseness of *Tsuga* pollen. Another is the later entrant into the forest complex of *Carya* than of *Quercus*. *Pinus* is persistent to the upper levels in the bogs of Early Wisconsin glaciation but never shows a definite climax. This is true in Turtle Pond regardless of the fact that there is a climax at the 4- and 5-foot levels on the graph. As stated previously, the first five levels at Turtle Pond are extremely sparse in pollen grains and the percentages given are unreliable. However, *Pinus* appears to be on the increase in the upper foot-levels of this peat deposit. Another similarity is that *Picea glauca* reaches a climax between maxima of *P. mariana*.

Bogs of the Early Wisconsin glaciation in Indiana have been studied by Barnett (1), Friesner and Potzger (8), Griffin (12), Howell (13), Otto (15), Prettyman (16), Richards (17), and Swickard (19).

Because of a study by Geisler (10), an attempt was made to separate grass pollens on the basis of size and exine thickness in order to determine the prairie species. However, the fossil grass pollens were too crushed to give accurate size measurement and the results of the measurements were omitted from the table.

The preliminary diatom study (table IV) is inconclusive because there are no other studies of fossil diatoms reported from this area. So, there is no comparison to be made. Some of the diatom species are characteristic in their presence or abundance at certain levels and may be correlated with certain events disclosed by the pollen spectrum (table I). It is hoped that with future analyses, the significance of the diatoms can be correlated with the history of climate in Illinois. A far more extensive study of micro-fossils from the numerous bogs in Illinois must be undertaken before any generalized statement can be made as to the climatic and vegetational changes which have occurred since the glacial retreat.

## SUMMARY AND CONCLUSIONS

1. Conifer pollens were dominant in the lower foot-levels, reaching over 90% at the 16- and 15-foot levels.

2. *Picea mariana* was the dominant conifer throughout the profile except at the 18-foot level where it was exceeded by *P. glauca*.

3. As *Picea* declined from its dominance, *Quercus* made its appearance, reaching its peak of 61% at the 10-ft. level, where the decline of conifers was nearly complete.

4. *Pinus strobus* never played an important role in the area around this bog.

5. *Carya* and *Ulmus* increased as *Quercus* declined from its 10-ft. peak, but at no foot-level did they exceed *Quercus*.

6. Except for the top 5 foot-levels where the results are probably unreliable, pollen frequency was lowest at the 13-ft. level. Maximum frequency was reached at the 10-ft. level.

7. The long period of low frequency of tree pollens (16- to 12-ft. levels) coincides with the first maximum for pollens of grasses and chenopods, indicating the possibility of a prairie invasion.

8. A second increase of prairie may be indicated by the decline in deciduous tree pollen in the 7- to 5-ft. interval.

9. The vegetational succession appears to have been from conifers to herbs to broadleaf trees to herbs.

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